PB-216 213

A STUDY OF THE EFFECT OF SEWAGE DISTRIBUTION ON HIGH RATE FILTER EFFICIENCY

W. Q. Kehr, et al

Public Health Service
Cincinnati, Ohio

December 1947

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

325

F167

LOAN COPY

A STUDY OF THE EFFECT OF SEWAGE DISTRIBUTION ON HIGH RATE FILTER EFFICIENCY

By

W. Q. KEHR and C. C. RUCHHOFT

Foreword by

W. SCOTT JOHNSON

DECEMBER 1941

DO NOT PHOTOGRAPH THIS PAGE

The Department of

PUBLIC HEALTH AND WELFARE OF MISSOURI

Division of Health

SECTION OF ENVIRONMENTAL SANITATION

and

THE UNITED STATES PUBLIC HEALTH SERVICE

Water and Sanitation Investigations Station

LIBRARY

ENVIRONMENTAL HEALTH CENTER

CINCINNATI, OHIO

PB 216 213

A STUDY OF THE EFFECT OF SEWAGE DISTRIBUTION ON HIGH RATE FILTER EFFICIENCY

By

W. Q. KEHR and C. C. RUCHHOFT

Foreword by

W. SCOTT JOHNSON

DECEMBER 1947

Details of illustrations in this document may be better studied on microfiche.

The Department of

PUBLIC HEALTH AND WELFARE OF MISSOURI

Division of Health

SECTION OF ENVIRONMENTAL SANITATION

and

THE UNITED STATES PUBLIC HEALTH SERVICE

Water and Sanitation Investigations Station

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

4517

MID-STATE PRINTING CO., JEFFERSON CITY, MO.

A STUDY OF THE EFFECT OF SEWAGE DISTRIBUTION ON HIGH RATE FILTER EFFICIENCY

FOREWORD

W. Scott Johnson

In June, 1941, the State Health Departments signatory to the Upper Mississippi River Drainage Basin Agreement—Illinois, Indiana, Iowa, Minnesota, Wisconsin and Missouri—sponsored a study of high daily rate trickling filter performance. During this study, operating data were obtained from nine sewage treatment plants located in Wisconsin, Minnesota, Iowa and Illinois. The results of these studies, published in a bulletin entitled "High Daily Rate Trickling Filter Performance," by Graham Walton, March, 1943, indicated that distributors based on the Halverson patents and of rather elaborate design, when used to apply sewage in the form of a "rain-like" spray, were very little, if any, more efficient than conventional distributors operating outside of the range covered by the Halverson patents.

Manufacturers of equipment designed to operate under the Halverson patents protested that the plants included in the study were not typical of plants designed and operated in accordance with their recommendations and that some plants were even utilizing equipment not designed to operate in the range covered by the Halverson patents. Further, in certain cases, unusual conditions resulting from the admixture of industrial wastes with the domestic sewage resulted in loadings well in excess of those recommended for plants of this type. As a result of these objections, members of the Upper Mississippi River Board of Public Health Engineers agreed to sponsor a further study of the effect of distribution on high rate sewage filter efficiency with the assistance of the U. S. Public Health Service, in any plant in any of the signatory states. The selection of the plant was to be made by the manufacturers of equipment licensed under the Halverson patents. Actually, because of certain requirements, there were only a few plants in this area available for the study—the one finally selected being located at Neosho, Missouri. Pursuant to agreements reached in several conferences between the Upper Mississippi River Board of Public Health Engineers and representatives of the manufacturers, the necessary changes to the Neosho plant were completed and the study started early in 1945 under the direct

supervision of Mr. W. Q. Kehr of the Missouri State Board of Health.* All laboratory work was undertaken by a mobile laboratory of the U. S. Public Health Service under the supervision of Mr. C. C. Ruchhoft. The laborious task of collecting 24-hour composite samples was accomplished by engineers of the Missouri and Illinois Health Departments. The laboratory work was performed by Messrs. W. A. Moore, A. L. Holman and R. G. Snapp of the U. S. Public Health Service.

Valued assistance and cooperation was extended by the municipal officials of Neosho and the Newton County Health Department. Acknowledgment is also made to the Lakeside Engineering Corporation for their cooperation in obtaining and installing conventional distributor arms and for their general assistance.

The following report, with included statistical data from this study, has been prepared and edited for publication by Mr. Kehr and Mr. Ruchhoft. It covers the operation during winter and summer conditions of two parallel filters equipped with different types of distributors and arrives at certain conclusions relative to the comparative effectiveness of the types of distribution employed under the operating conditions of this study.

November, 1946.

---

*Revisions to the Missouri Constitution which became effective July 1, 1946, changed the State Board of Health of Missouri to the Division of Health of the Department of Public Health and Welfare of Missouri.

SUMMARY

A study was made of the effect of sewage distribution on the efficiency of high rate sewage filters at Neosho, Missouri, by the Missouri State Board of Health and the U. S. Public Health Service, at the request of the Upper Mississippi River Board of Engineers.

The Neosho municipal sewage treatment plant has two parallel, high-rate filters of the "Aerofilter" type and was designed for a population of 12,000 and a population equivalent of 22,500, the industrial wastes consisting principally of the wastes from a large milk condensery. The design of the plant was such that conditions were almost ideal for the type of study undertaken. The arms of one of the Lakeside "Aerofilter" distributors originally installed at the plant were replaced with four straight arms and the speed adjusted so that instantaneous applied flow rates were outside the range covered by the basic Halverson patents.

The first period of study extended from March 19 to April 11, 1945, and the second from July 12 to August 8. Twenty 24-hour composite and five 4-hour composite samples were collected and analyzed from each sampling point during the first period and twenty-four 24-hour composite and two 4-hour composite samples during the second. In addition, grab samples were collected for analysis during both periods for dissolved oxygen, B.O.D. of the digester supernatant, and special determinations.

There was no significant difference in the efficiency of the two filters in the removal of B.O.D. or suspended solids in the loading ranges studied. The quantity of B.O.D. removed plotted against loadings followed a straight line trend rather closely. The curve of best fit for the second period had a slightly higher position and less slope than during the first period. This was undoubtedly due to the higher temperatures and heavier loadings encountered during the latter period. Although the applied loadings exceeded 2.5 pounds of B.O.D. per cubic yard for both filters, there was no indication of a break from the straight-line trend in either case.

Loadings were generally low during the first period due to a heavy infiltration condition and the necessity for by-passing a portion of the sewage. During the second period the loadings were much heavier and approximated plant design loadings.

During the last four days of the second period, the maximum possible volume of effluent was recirculated to study filter operation under these conditions. Except for slightly higher removals by both filters, no significant changes were apparent.

A special study was made to determine the effectiveness of the so-called "raindrop" application of sewage to the filter in increasing the dissolved oxygen content of the applied sewage. Although there appeared to be an increase of 1.0 p.p.m. in the dissolved oxygen content of the sewage applied to the "Aerofilter" over that applied to the conventional filter, the increase did not carry through the filter, and there was no appreciable difference in the dissolved oxygen content of the two effluents. This was confirmed by the results of several series of grab samples of the effluents from both filters collected during the study.

There was no significant difference in the nitrification occurring in the two filters. During the first period of study the average nitrate content of both filters exceeded 4.0 p.p.m. During the latter period, when loadings approaching those for which the plant was designed were encountered, the nitrate content of both filters dropped to less than 0.2 p.p.m.

A careful study was made of the relationship between filter loadings and nitrification. Of the various parameters used, best correlation was obtained between the quantity of B.O.D. removed and the quantity of nitrites and nitrates produced per 100 pounds of B.O.D. removed. Above a critical load, which was slightly different for the two filters, nitrification was negligible. Below the critical load the filter equipped with an "Aerofilter" distributor gave slightly better nitrification. As nitrification was negligible during the second period, the study was limited largely to data collected during the first period.

Sewage distribution studies made during this survey did not include momentary rates of application to the filter surface but were limited to a comparative study of the ability of the two distributors to apply the sewage evenly along a given radius. The co-efficients of distribution obtained were not materially different for the two distributors and the limited data obtained during the study of these filters does not permit significant interpretation without further study.

A STUDY OF THE EFFECT OF SEWAGE DISTRIBUTION ON HIGH RATE FILTER EFFICIENCY

By W. Q. Kehr and C. C. Ruchhoft

INTRODUCTION

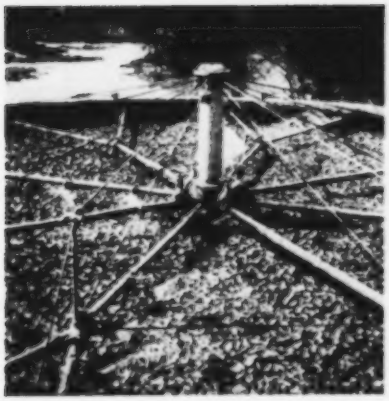
At the request of the Upper Mississippi River Board of Public Health Engineers, a study was undertaken to determine the effect of sewage distribution on the efficiency of high-rate filters. To study this variable, it was decided that the plant selected should be so designed and constructed that two high-rate filters, utilizing different types of distributors, could be operated in parallel. After considering the various high-rate filter plants in the states signatory to the Upper Mississippi River Basin Sanitation Agreement, the municipal sewage treatment plant at Neosho, Missouri, was selected as most suitable for the study. Accordingly, arrangements were made with the city officials at Neosho to permit alteration of the filter distributors and conduct the study. The Lakeside Engineering Company of Chicago, who furnished the original "Aerofilter" distributors at the Neosho plant, co-operated in obtaining distributor arms of a conventional type from the Pacific Flush Tank Company, and replacing the "Aerofilter" distributor arms on one of the filters with these. As the filters are identical, a direct comparison could be made of the efficiency of the two types of distribution. The capacities of the two distributors were different, resulting in a slightly higher percentage of the flow and load going to the "Aerofilter" during the first period. During the second period, however, a high percentage of the flow was shifted to each filter alternately in order to obtain heavier loadings. Although the daily rate of sewage application to the filter surface fell below that normally recommended for several days, no deterioration of the effluent was apparent.

The original plan was to study the effect of the two types of distributors for one month during both winter and summer seasons. However, due to delay in completing the filter distributor replacement and the necessity for a period of tuning up to insure the complete adjustment of the filter growths to the altered distributor, it was March 19 before the first comparative tests were run. These tests were continued under the difficulties of a rainy spring, with a resulting weak sewage until April 11, when a cloudburst abruptly terminated the first period of study. The temperature during the second period (July 12 to August 8) was normal for the season, and the difference in temperature was sufficient for the purposes of this study.

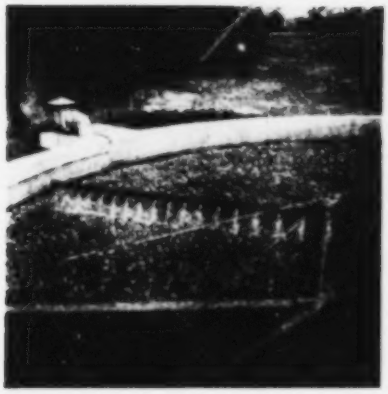
NEOSHO PLANT ILLUSTRATIONS

Two filters with distribution box between them

Distribution box



Aerofilter distributor in operation



Conventional distributor in operation (Aerofilter arms not operating).

Originally, a study of the biology of the two filters was contemplated. It is regrettable that circumstances prevented the completion of this study.

The Neosho study was not intended to be a study of the efficiency of deep high-rate sewage filters. The results obtained of the efficiencies of the two filters studies are considered, therefore, to be incidental except for their comparative value in studying any differences which might be attributed to the two distributors used in applying the sewage to the filter surface.

Although the strength of the sewage varied widely, no attempt has been made to include in this study the effect of the strength of the applied sewage on filter efficiency. If the data are grouped into several ranges according to the applied load expressed either as parts per million B.O.D. or pounds of B.O.D. per cubic yard, it will be immediately evident that the distribution of the data is such that most groups are too small to provide any reasonable degree of accuracy. Further, the results obtained during the two periods of study can not be combined for this purpose because of the presence of such variables as temperature, nitrification, and the percentage distribution of the sewage flow to each of the two filters.

DESCRIPTION OF PLANT

The Neosho sewage treatment plant is of the separate sludge digestion type utilizing two high-rate filters operating in parallel for secondary treatment. The effluent is discharged into Shoal Creek, which has a minimum flow sufficient to provide a dilution of three to five parts of stream water to one part of effluent. The plant was originally designed for primary treatment with provision for the addition of chemicals when necessary. In 1943 the capacity of the plant was increased and secondary treatment added as a result of the greatly increased population, due to the construction of Camp Crowder nearby, and also to provide a greater factor of safety for the Joplin, Missouri, water supply, which is taken from Shoal Creek.

The Neosho plant consists of the following units: A Parshall flume controlled proportional flow grit chamber; a comminutor; two rectangular primary settling basins equipped with sludge collection mechanism; a wet well equipped with 4 turbine type pumps having capacities of 600, 1000, 1200 and 1400 g.p.m.; two 55-foot diameter high-rate filters equipped with Lakeside distributors having 8 branched arms; two rectangular final settling tanks equipped with sludge collection mechanism; two sludge digestion tanks, one of which is equipped with mechanism and heating coils, and the other with a wooden floating cover; and sludge drying beds. A recording and totalizing flow meter is connected to the Parshall flume.

Each filter was equipped with two blowers to provide forced draft ventilation. These blowers were operated continuously throughout the study to minimize any possible variation in ventilation in the two filters.

The plant was designed for a population of 12,000 plus an industrial load, consisting principally of milk wastes from a condensery, having a population equivalent of 10,500. The design capacities, loadings, and detention periods for the various units are as follows:

	Capacity	Detention Period or Loading
Primary Settling Tanks	129,250 gallons	1.38 hrs.
High Rate Filters	1407.9 cubic yards	2.0 lbs. per cu. yd. applied
Final Settling Tank	127,304 gallons	1.36 hrs.
Sludge Digestion Tanks	30,042 cu. feet	2.0 cu. ft. per capita plus industrial wastes

It should be mentioned that by means of a programmed float control switch, the sewage lift pumps operate through the range of 1000-2200 g.p.m. by 200 g.p.m. increments, with the 600 g.p.m. pump operating in addition to the 1000 and 1200 g.p.m. pumps when the flow exceeds 2200 g.p.m. Provision is made for automatic recirculation when the flow falls below 1000 g.p.m.

SCOPE OF PROJECT

The primary objective of the project was to determine whether the continuous application of sewage in the form of "rain-like" spray is necessary to obtain the maximum efficiency, as measured by the removal of 5-day B.O.D., from high-rate sewage filters. Further, if the application of sewage in the form of "rain-like" spray does give a higher efficiency, can the increased efficiency obtained by rather elaborate distribution devices be justified economically.

It was originally intended to make two series of observations, one in mid-winter and the other in mid-summer to determine what effect, if any, extreme weather conditions might have on the results of the study. Unfortunately, as previously stated, the start of the project was delayed until spring. However, the average temperature during the first run was well below that encountered during mid-summer and it is believed that the final results reflect the effect of temperature variations.

During the entire study a series of 44 observations were made on 24-hour composite samples, 7 on 4-hour composites collected during the daily peak period, and many individual observations of the dissolved oxygen content of the filter effluents, B.O.D. of the digester supernatant and special samples which it was felt might have some bearing on the results

obtained. During the latter part of the study, four days were devoted to the effect of recirculation on filter efficiency. The capacity of the recirculation line was limited, resulting in an average return flow during the 4-day period slightly less than the incoming sewage flow.

It was hoped that the results would extend over a sufficient range to determine the point at which the efficiency of each filter dropped, as well as to determine the trend of the efficiency with load. It is apparent, however, that for the two filters observed any break from the straight-line trend lies above the loading ranges encountered.

Rather complete nitrogen determinations were made on all 24-hour and many 4-hour composites with the hope of studying closely the nitrification which occurs in high-rate filters, and particularly the effect of the distribution on nitrification.

As a check on the ability of the distributors to apply the sewage evenly along a given radius, a study was made of the performance of each distributor under the various flow and operating conditions encountered during the study. A special study was also made to determine whether the application of sewage to a filter in the form of a "rain-like" spray was effective in increasing the dissolved oxygen content of the applied sewage.

COLLECTION OF SAMPLES

Samples were collected at 30-minute intervals from all sampling points. In collecting the 24-hour composite samples, no attempt was made to take into consideration the time lag through the plant due to detention periods in the various plant units. In the collection of 4-hour composite samples, however, the detention period, based upon the average flow, was determined for each unit and the collection of samples staggered accordingly.

Twenty-four hour composite samples were collected of the raw sewage, settled sewage, applied sewage (since there was no recirculation except for the last four days of the second period, the settled and applied samples were the same except for the time lag through the wet well), each filter effluent, and plant effluent. Since the effluent from each filter could not be settled separately, it was necessary to collect a sufficient quantity of the effluent from each filter to permit settling in liter graduated cylinders. One hour's settling under quiescent conditions in a graduated cylinder resulted in a supernatant comparable to the effluent from the final settling tanks.

Samples for 4-hour determinations were collected of the raw and applied sewage and from each filter effluent. As in the case of the 24-hour samples, it was necessary to settle the filter effluent in cylinders and remove the supernatant for analysis.

Grab samples for the determination of dissolved oxygen were collected of each filter effluent, of the combined filter effluents (from the main channel following the filters), and of the final effluent. In addition, frequent samples were collected of the digester supernatant and B.O.D. determinations made as a check on digester operation.

The quantity of sewage collected at each sampling period was proportional to the flow and was so adjusted as to bring the total volume to approximately 2 liters

In collecting samples for the special study of the effectiveness of a "rain-like" spray to increase the dissolved oxygen content of the applied sewage, a 10% solution of copper sulphate was used to inhibit oxygen utilization during collection and analysis. This solution was added to a pan set flush with the filter surface before the collection of distributor samples because it was generally necessary for the distributor to make several revolutions before a sufficient quantity of sample had been collected. The procedure followed was to collect a sample of sewage from the head box preceding the filter and set up several samples for an initial D.O. analysis and short time B.O.D.s (15 to 45 minutes) at sewage temperature. A sample was then collected from one distributor and the effluent from that filter, then from the other distributor and filter effluent. Finally a second sample was collected from the head box to note any change in the dissolved oxygen content of the sewage going to the distributor. The time of collection was carefully noted, and the delay between collection and analysis reduced to a minimum by arranging for the analytical work to proceed while other samples were being collected. The order and time of collection was carefully worked out to minimize any error which might occur as a result of a change in the D.O. content of the sewage reaching the distributors.

For the purpose of studying distribution on the two filters, a series of pans 3 inches wide and 12 inches long were set flush with the filter surface along one radius, the long side normal to the radius. The distributor was then rotated one or more times (depending on the rate of flow), the pans removed and the depth of sewage in each pan measured and recorded. The distributor was given a push at the start to bring it immediately to normal operating speed. In order to obtain the depth for each 6-inch concentric ring, the depths in the two pans in that ring were averaged. The time required for the distributor to make the desired number of revolutions was recorded. In addition to the co-efficients proposed by Walton[1] the co-efficient of variation and standard deviation, from the mean depth, both standard statistical procedures, were calculated.

ANALYTICAL PROCEDURES

In general, Standard Methods for the Examination of Water and Sewage, eighth edition, 1936, published by the American Public Health Association was followed throughout the study. Deviations from these methods were made in the case of pH determinations, the dissolved oxygen procedures for B.O.D., the dilution water for B.O.D. and the dissolved oxygen determinations made on applied sewage samples.

The pH determinations were made colorimetrically with an SDC kit. The results obtained with this kit were checked occasionally electrometrically with a Leeds and Northrup portable electrometric assembly using the small glass electrode.

The dissolved oxygen determinations for all B.O.D. analyses were made with a modified Winkler method using sodium azide (8.0 grams per liter) in the alkaline-iodide solution as described by Barnett[2]. A comparative study showing the excellence of this procedure in B.O.D. work has been presented by Placak and Ruchhoft[3]. The Theriault and Nichols mineralized phosphate-buffered water which was studied and reported on favorably for use in sewage studies by the Standard Methods Committee of the Federation of Sewage Works Association[4], was used in all B.O.D. determinations.

In making the dissolved oxygen study on the applied sewage from the head box and the distributors, care had to be taken to inhibit biochemical oxidation and interference from organic matter during the determinations. On the basis of the work of Ruchhoft and Placak[5] 10 ml. of 10% copper sulfate solution per liter of sewage collected was added to the collecting tray. Copper sulfate was used in this case in preference to the copper sulfate-sulfamic acid inhibitor because the lower rate of oxidation to be inhibited permitted its use and because of the corrosiveness of the acid inhibitor to the metal pans used for catching the sewage. The inhibited sewage was then immediately carefully siphoned into 250 ml. glass stoppered bottles and the short Winkler technique was applied at once. In this technique 2. ml. of manganous sulfate solution and 2. ml. of the alkaline iodide solution containing sodium azide are added and the sample is vigorously shaken for 30 seconds. Then without waiting for the precipitate to settle the sample is acidified, shaken again, measured out and titrated with 0.025 N sodium thiosulfate as quickly as possible. In all of these special dissolved oxygen studies each sample was carried through all operations from collection to titration without any delay. Previous work at the Cincinnati Station indicates that the dissolved oxygen values obtained by this technique at Neosho should be reasonably close to that actually present in the applied sewage.

RESULTS

B.O.D. Determinations: The detailed results of all B.O.D. determinations will be found in Appendix B. In addition, these results have been summarized in various forms for convenience in Tables 1 and 2. In Table 1 will be found the daily quantity of B.O.D. in pounds computed for the various sampling points; in Table 2 the filter loadings and removals expressed in pounds of B.O.D. per cubic yard of rock, the percentage removal by the primary tank, and the overall percentage removal.

In addition to the above, a table was prepared for the progress report to show the trend of efficiency with time and load during the first period. It was feared that insufficient time might have elapsed to permit the filter utilizing the conventional distributor to become stabilized. As the trend in both filters was the same, it was concluded that stabilization had occurred prior to the start of the project. The data were inconclusive with reference to the trend of efficiency with load during the first period. Later an attempt to determine such a trend for both periods was inconclusive because of the marked difference in temperature as well as load during the two periods.

Figure 1 shows the B.O.D. loadings and removals for Filter A (Aerofilter distributor) during the entire study. Each circle represents the results of the analysis of a 24-hour composite sample. For clarity, the results of the analysis of 4-hour composite samples and samples collected during the period when recirculation was employed have been omitted. The curve of best fit, as computed by the method of the least squares for the data plotted is shown. Similar data for Filter B (conventional distributor) have been plotted on Figure 2. The curves of best fit, based on the results of the entire study, exclusive of the last 4 days when recirculation was employed, were calculated to be:

Filter A (Aerofilter distributor) $y = 0.8036x - 0.0972$
Filter B (conventional distributor) $y = 0.7212x + 0.0045$

Where $x =$ Pounds of B.O.D. applied per cubic yard, and
$y =$ Pounds of B.O.D. removed per cubic yard.

A careful study of Figures 1 and 2 will disclose that within the limits of data obtained, there is no indication of a break in the straight-line trend.

On Fig. 3 the two curves of best fit have been plotted, together with recirculation data, means of the 4-hour composites during each of the two periods of study, and the loading curve developed by the Lakeside Engineering Corporation. It will be observed that the two curves of best fit cross at a loading of 1.13 lbs. per cubic yard and that the curve for the Aerofilter is slightly steeper than for the filter with the conventional distributor. It should be kept in mind that 44 individual observa-

TABLE 1
DAILY POUNDS OF SUSPENDED SOLIDS AND 5-DAY BOD

Date 1945	Influent Sewage				Aerofilter Distributor				Conventional Distributor				Effluent	
	Raw		Settled		Applied		Settled Effluent		Applied		Settled Effluent			
	Suspended solids	5-day BOD	Suspended solids	5-day BOD	Suspended solids	5-day BOD	Suspended solids	5-day BOD	Suspended solids	5-day BOD	Suspended solids	5-day BOD	Suspended solids	5-day BOD
					Samples Composited Over 24-Hour Period									
Mar. 19	1298	2686	1132	1554	628	922	347	339	519	761	293	283	679	498
20	1215	2130	815	1201	548	673	216	154	395	485	150	123	558	357
21	1340	1067	782	707	355	512	187	161	303	437	183	103	372	298
24	2219	1818	1350	1243	542	704	573	251	420	546	403	180	709	508
25	1698	1554	1209	1238	690	767	366	302	476	529	253	186	533	475
26	1246	1479	1136	1397	654	749	271	288	469	538	183	153	411	370
27	1173	1963	1224	1058	625	603	223	227	484	467	167	160	344	382
28	1300	1391	1001	1196	595	679	266	203	510	581	198	195	468	351
29	2161	2351	1256	1811	676	963	387	295	522	744	248	209	584	394
30	1262	1133	1076	1004	579	599	257	244	454	470	303	194	402	373
Apr. 1	2205	1445	1282	954	695	669	271	191	527	507	308	123	596	417
2	1413	1987	.....	1525	593	905	364	272	457	698	244	203	434	462
3	2094	2953	1047	1785	534	964	282	324	406	734	319	222	376	483
4	1819	1939	1230	1511	604	847	250	266	493	691	288*	157*	361	401
5	1658	2384	1407	1955	696	1120	284	379	503	810	168	245	444	563
7	1328	3081	1023	1647	537	973	306	293	419	760	210	200	345	438
8	1506	1183	1122	1602	726	937	382	237	547	707	206	170	301	424
9	1726	2608	1349	1946	609	1047	332	326	468	806	203	222	117	563
10	2353	2190	1535	1586	698	878	277	214	510	641	250	149	478	277
11	1658	2146	1182	1529	743	916	353	221	555	684	258	202	360	373
Mean	1634	1974	1166	1422	616	821	300	259	472	630	239	185	444	410
			Samples Composited Over Maximum 4-Hour Period						(Computed on 24-Hour Basis)					
Mar. 26	2731	3530	.....	.....	973	1490	438	464	659	1009	362	267	.....	.....
28	1625	2577	.....	.....	576	1021	270	312	612	1084	383	300	.....	.....
Apr. 4	1289	6174	.....	.....	510	2025	405	607	389	1544	266	476	.....	.....
7	1568	3669	.....	.....	765	1743	434	476	539	1229	240	300	.....	.....
10	2268	3724	.....	.....	697	2043	722	470	501	1469	117	303	.....	.....
Mean	1896	3935	.....	.....	704	1664	454	466	540	1267	274	329	.....	.....

*Regular sample broken. Used 24-hour composite filter effluent sample after settling 1 hour. Omitted from average.

TABLE 1—Continued
DAILY POUNDS OF SUSPENDED SOLIDS AND 5-DAY B.O.D.

Date 1945	Influent Sewage				Aerofilter Distributor				Conventional Distributor				Effluent	
	Raw		Settled		Applied		Settled Effluent		Applied		Settled Effluent			
	Suspended solids	5-day B.O.D.	Suspended solids	5-day B.O.D.	Suspended solids	5-day B.O.D.	Suspended solids	5-day B.O.D.	Suspended solids	5-day B.O.D.	Suspended solids	5-day B.O.D.	Suspended solids	5 day B.O.D.
July 12	3323	2730	1572	1602	605	788	258	143	715	933	338	257	786	519
13	2707	3628	1987	3427	665	1493	378	443	803	1804	457	693	921	1541
14	2287	3245	2001	3459	610	1513	413	426	762	1890	484	619	843	1029
15	1827	2754	1451	2459	545	1090	326	308	691	1382	511	458	820	806
16	2659	4045	1856	3172	727	1387	370	401	907	1729	523	538	706	970
18	2900	2751	1721	2697	739	1079	372	280	1118	1632	547	547	813	917
19	2462	3336	1747	2409	474	717	212	146	1154	1746	601	521	649	748
20	2309	3051	1553	2612	473	762	189	118	1039	1671	812	420	591	474
21	2371	3250	1757	2999	953	1768	469	430	776	1440	307	307	725	962
22	1964	3058	1459	2974	848	1725	349	352	752	1530	244	264	435	1129
24	2415	3449	1673	3187	990	1829	503	570	727	1343	283	256	728	866
25	2093	3013	1325	2553	813	1579	332	379	624	1211	188	209	502	621
26	2219	3288	1397	3205	841	1635	270	365	611	1187	179	236	507	616
27	2484	2568	1580	4389	978	1867	424	345	715	1365	280	213	607	689
28	1854	3250	1585	2646	904	1356	369	255	708	1062	242	224	551	551
30	2558	3406	1669	4631	610	1044	215	186	1221	2092	557	687	552	883
31	2293	3205	1094	2462	495	678	138	182	1094	1498	386	540	456	519
Aug. 1	3331	3382	1361	3548	603	1067	181	130	1431	2532	528	557	318	637
2	2941	5651	1774	5007	730	1378	236	184	1749	3300	660	952	778	1043
3	2214	3588	1552	2876	502	863	243	146	1051	1809	560	442	674	863
5	1349	2890	1108	2661	471*	1487*	235*	199*	3372*	1174*	159*	164*	422	384
6	2396	3179	1686	2662	910*	1545*	403*	269*	658*	1117*	261*	183*	710	611
7	2222	3346	1430	2669	729*	1588*	251*	235*	497*	1082*	197*	123*	511	409
8	2476	3194	1386	2575	664*	1536*	266*	208*	450*	1039*	200*	121*	532	400
Mean	2402	3302	1572	3037	703	1324	308	279	859	1565	396	397	631	758
			Samples	Composited Over	Maximum 4-Hour Period				(Computed on 24-Hour Basis)					
July 22	3138	6809	.....	.....	1618	4416	553	751	1386	3784	340	488	.....	.....
27	4652	7059	.....	.....	1923	4294	863	1056	1093	2441	416	451	.....	.....
Mean	3895	6934	.....	.....	1771	4355	708	904	1240	3113	378	470	.....	.....

*Flows used for computing these values based upon % of settled sewage flow going to each filter. Analysis of primary settling tank effluent used in place of applied sewage in computing applied values.

TABLE 2

REMOVALS OF B.O.D. AND SUSPENDED SOLIDS, AND FILTER LOADINGS

Except for Percentages, Results Expressed in Pounds per Cubic Yard Filter Media

Date 1945	Primary		Aerofilter Distributor								Conventional Distributor								Overall	
	% Removed		Applied		Settled Effluent		Removed		% Removed		Applied		Settled Effluent		Removed		% Removed		Per Cent Removed	
	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.
Mar. 19	42.1	12.8	1.31	0.89	0.48	0.49	0.83	0.40	63.2	44.7	1.08	0.74	0.40	0.42	0.68	0.32	63.8	43.4	81.8	47.7
20	43.6	32.9	0.96	0.78	0.22	0.31	0.74	0.47	77.2	60.6	0.69	0.86	0.17	0.21	0.51	0.35	74.7	62.1	93.2	84.1
21	33.7	41.7	0.73	0.50	0.23	0.27	0.50	0.24	68.6	47.2	0.62	0.43	0.15	0.26	0.47	0.17	76.8	39.6	72.1	72.2
24	31.6	39.2	1.00	0.77	0.36	0.81	0.64	0.04	64.4	5.6	0.77	0.60	0.26	0.60	0.51	0.00	67.1	0.0	72.1	68.0
25	20.4	28.8	1.09	0.98	0.43	0.52	0.66	0.46	60.6	46.9	0.75	0.68	0.26	0.36	0.49	0.32	64.9	46.9	69.4	68.6
26	5.6	8.8	1.06	0.93	0.41	0.38	0.65	0.54	61.6	58.5	0.76	0.67	0.22	0.26	0.55	0.41	71.6	61.0	76.0	67.0
27	46.1	4.4	0.86	0.80	0.32	0.32	0.53	0.57	62.4	64.4	0.66	0.89	0.23	0.24	0.44	0.45	65.7	65.5	80.5	70.7
28	14.0	23.0	0.97	0.85	0.29	0.38	0.68	0.47	70.1	55.3	0.83	0.72	0.28	0.28	0.55	0.44	66.5	61.2	74.8	64.0
29	23.0	41.9	1.37	0.96	0.42	0.55	0.95	0.41	69.4	42.7	1.06	0.74	0.30	0.35	0.76	0.39	71.9	52.4	83.2	73.0
30	11.4	14.8	0.85	0.82	0.35	0.37	0.50	0.46	59.3	55.6	0.67	0.65	0.28	0.43	0.39	0.21	58.8	33.3	67.1	68.1
Apr. 1	34.0	41.9	0.95	0.99	0.27	0.39	0.68	0.60	71.5	61.0	0.72	0.75	0.18	0.44	0.54	0.31	75.7	41.5	71.1	73.0
2	.....	76.7	1.29	0.84	0.39	0.52	0.90	0.33	70.0	38.7	0.99	0.65	0.29	0.38	0.70	0.30	70.9	46.7	76.7	69.3
3	50.0	83.6	1.37	0.76	0.46	0.40	0.91	0.36	66.4	47.1	1.04	0.58	0.32	0.45	0.73	0.12	69.7	21.4	83.6	82.0
4	32.4	79.3	1.20	0.86	0.38	0.36	0.83	0.50	68.6	58.6	0.98	0.70	0.22*	0.41*	0.76*	0.29*	77.2*	41.5*	79.3	80.2
5	18.0	15.2	1.59	0.99	0.54	0.40	1.05	0.59	66.2	59.3	1.15	0.71	0.35	0.24	0.80	0.48	69.7	66.7	76.4	73.2
7	46.6	23.0	1.38	0.76	0.42	0.43	0.97	0.33	69.9	43.1	1.08	0.60	0.28	0.30	0.80	0.30	73.6	50.0	85.8	74.0
8	35.4	25.5	1.33	1.03	0.34	0.54	0.99	0.49	74.7	47.3	1.00	0.78	0.24	0.29	0.76	0.48	75.9	62.4	84.2	80.0
9	25.4	21.8	1.49	0.86	0.46	0.19	1.02	0.68	68.8	78.3	1.14	0.67	0.32	0.29	0.83	0.38	72.4	56.6	86.1	93.2
10	27.6	34.8	1.25	0.99	0.30	0.39	0.94	0.60	75.6	60.4	0.91	0.72	0.21	0.35	0.70	0.37	76.8	51.1	87.4	79.7
11	28.7	28.7	1.30	1.06	0.31	0.50	0.99	0.55	75.9	52.5	0.97	0.79	0.29	0.37	0.68	0.42	70.4	53.5	82.6	78.3
Mean..	25.1	27.0	1.17	0.88	0.37	0.43	0.80	0.45	68.2	50.8	0.89	0.67	0.26	0.35	0.63	0.33	70.6	47.8	77.6	71.5
					Samples Composited Over Maximum 4-Hour Period (Computed on 24-Hour Basis)															
Mar. 26	.....	.....	2.12	1.38	0.66	0.62	1.46	0.76	68.9	55.0	1.43	0.94	0.38	0.51	1.05	0.42	73.5	45.4	.....	.....
28	.....	.....	1.45	0.82	0.44	0.38	1.01	0.43	69.4	53.1	1.54	0.87	0.43	0.54	1.11	0.33	72.2	37.4	.....	.....
Apr. 4	.....	.....	2.88	0.73	0.86	0.58	2.01	0.15	70.0	20.6	2.19	0.55	0.68	0.38	1.52	0.17	69.2	31.0	.....	.....
7	.....	.....	2.48	1.09	0.68	0.62	1.80	0.47	72.7	43.3	1.75	0.77	0.43	0.34	1.32	0.42	75.6	55.5	.....	.....
10	.....	.....	2.90	0.99	0.67	1.03	2.23	0.04	77.0	3.6	2.09	0.71	0.43	0.17	1.66	0.55	79.4	76.6	.....	.....
Mean..	.....	.....	2.37	1.00	0.66	0.65	1.70	0.35	71.6	33.7	1.80	0.77	0.47	0.39	1.33	0.38	74.0	49.2	.....	.....

*Regular sample broken. 24-hour composite conventional filter effluent sample mixed, settled 1 hour and used as replacement.

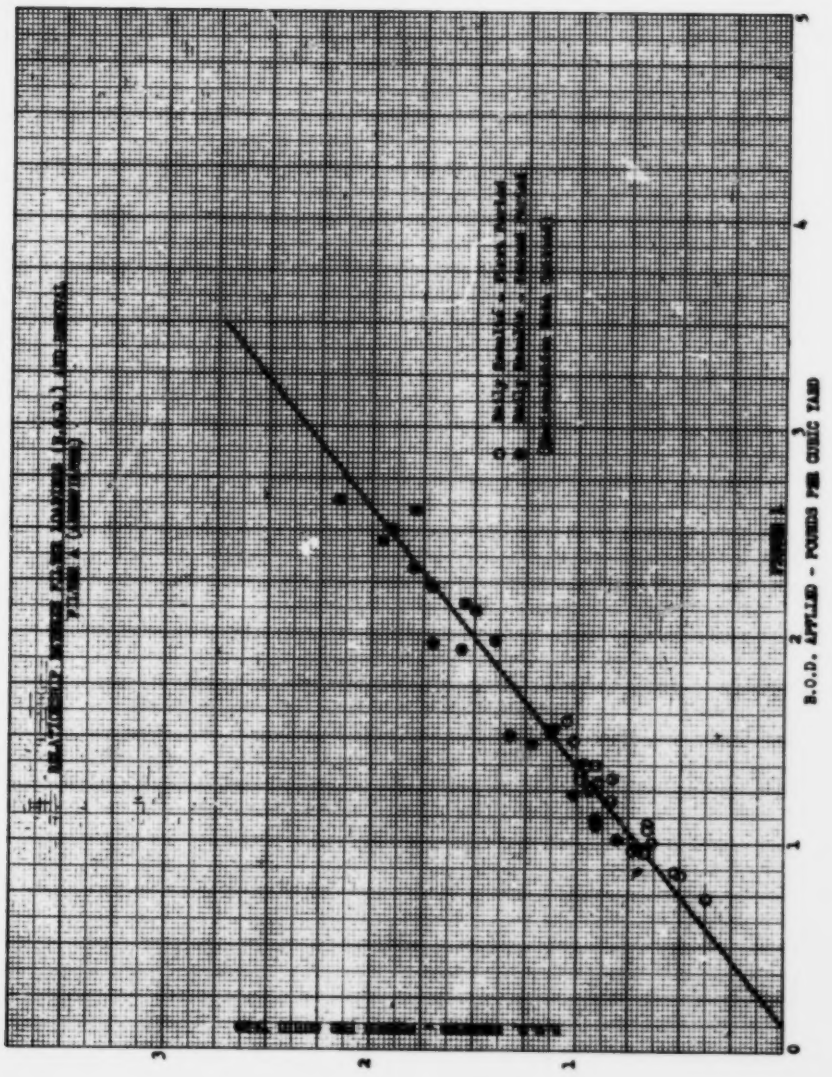
TABLE 2—Continued

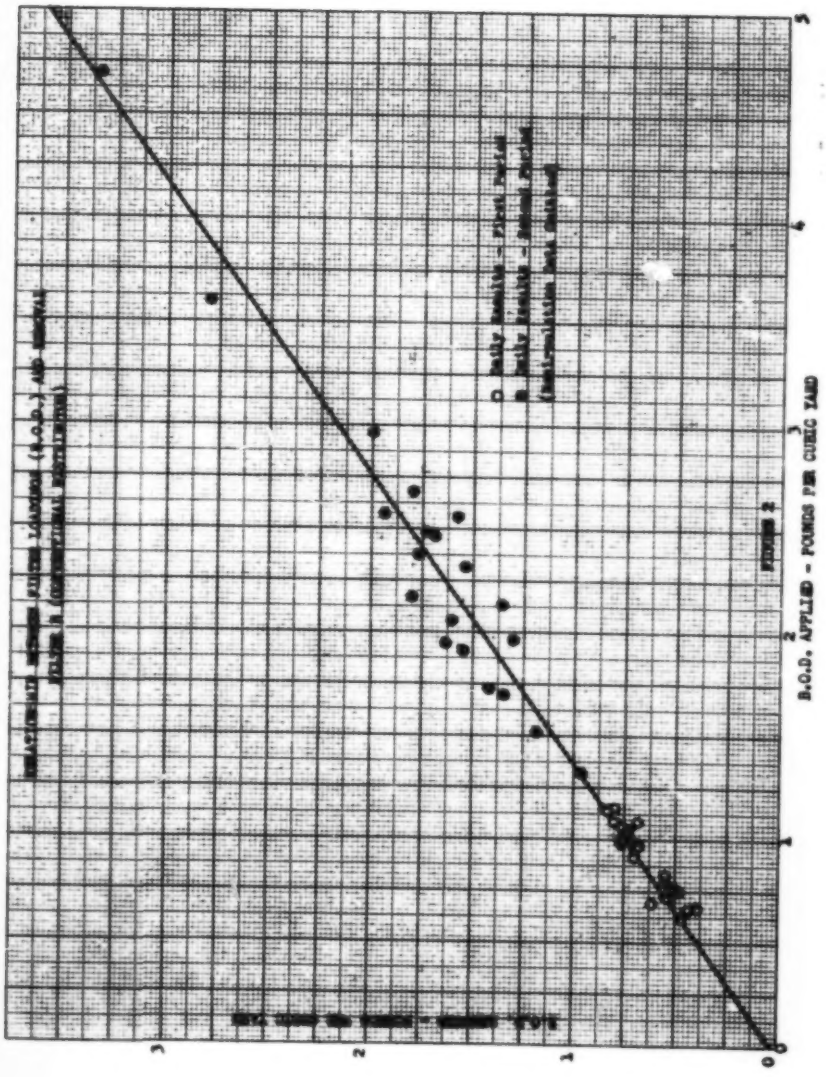
REMOVALS OF B.O.D. AND SUSPENDED SOLIDS, AND FILTER LOADINGS

Except for Percentages, Results Expressed in Pounds Per Cubic Yard Filter Media

Date 1945	Primary		Acrofilter Distributor								Conventional Distributor								Overall	
	% Removed		Applied		Settled Effluent		Removed		% Removed		Applied		Settled Effluent		Removed		% Removed		Per Cent Removed	
	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.
July 12	41.3	52.7	1.12	0.86	0.20	0.37	0.92	0.49	81.9	57.0	1.32	1.02	0.37	0.48	0.96	0.54	72.4	52.9	81.0	76.3
13	5.6	26.6	2.12	0.94	0.63	0.54	1.49	0.41	70.3	43.6	2.56	1.14	0.98	0.65	1.58	0.49	61.6	43.0	57.5	66.0
14	.....	12.5	2.15	0.87	0.60	0.59	1.54	0.28	71.9	32.2	2.68	1.08	0.88	0.69	1.80	0.39	67.2	36.1	68.3	63.1
15	10.7	20.6	1.55	0.77	0.44	0.46	1.11	0.31	71.7	40.3	1.96	0.98	0.65	0.73	1.31	0.26	66.9	26.5	70.7	55.2
16	21.6	30.2	1.97	1.03	0.57	0.53	1.40	0.51	71.1	49.5	2.46	1.29	0.76	0.74	1.69	0.55	68.9	42.6	76.0	73.4
18	2.0	40.7	1.53	1.05	0.40	0.53	1.13	0.52	74.0	49.5	2.32	1.59	0.78	0.78	1.54	0.81	66.5	50.9	66.8	72.0
19	27.8	29.0	1.02	0.67	0.21	0.30	0.81	0.37	79.6	55.2	2.48	1.64	0.74	0.85	1.74	0.79	70.2	48.2	77.6	73.7
20	14.4	32.7	1.08	0.67	0.17	0.27	0.91	0.40	84.5	59.7	2.37	1.48	0.60	1.15	1.77	0.32	74.9	21.6	84.5	74.4
21	7.7	28.9	2.51	1.35	0.61	0.67	1.90	0.69	75.7	51.1	2.05	1.10	0.44	0.44	1.61	0.67	78.7	60.9	70.4	69.4
22	2.8	25.7	2.45	1.20	0.50	0.50	1.95	0.71	79.6	59.2	2.17	1.07	0.37	0.35	1.80	0.72	82.8	67.3	63.1	77.9
24	7.6	30.7	2.60	1.41	0.81	0.71	1.79	0.69	68.8	48.9	1.91	1.03	0.36	0.40	1.55	0.63	81.0	61.2	74.9	69.9
25	15.3	36.7	2.24	1.15	0.54	0.47	1.71	0.68	76.0	59.1	1.72	0.89	0.30	0.27	1.42	0.62	82.8	69.7	79.4	76.0
26	2.5	37.0	2.32	1.19	0.52	0.38	1.80	0.81	77.7	68.1	1.69	0.87	0.34	0.25	1.35	0.61	80.1	70.1	81.3	77.2
27	.....	36.4	2.65	1.39	0.49	0.60	2.16	0.79	81.5	56.8	1.94	1.02	0.30	0.40	1.64	0.62	84.4	60.8	73.2	75.6
28	18.6	14.5	1.93	1.28	0.36	0.52	1.56	0.76	81.2	59.4	1.51	1.01	0.32	0.34	1.19	0.66	78.9	65.3	83.1	70.3
30	.....	34.7	1.48	0.87	0.26	0.31	1.22	0.56	82.2	64.4	2.97	1.73	0.98	0.79	2.00	0.94	67.2	54.3	74.1	78.4
31	23.2	52.3	0.96	0.70	0.26	0.20	0.70	0.51	73.2	72.9	2.13	1.55	0.77	0.55	1.36	1.01	64.0	65.2	83.8	80.1
Aug. 1	.....	59.2	1.52	0.86	0.18	0.26	1.33	0.60	87.8	69.8	3.60	2.03	0.79	0.75	2.80	1.28	78.0	63.1	81.2	90.5
2	11.4	39.7	1.96	1.04	0.26	0.34	1.70	0.70	86.7	67.3	4.69	2.48	1.35	0.94	3.34	1.55	71.2	62.5	81.6	73.6
3	19.9	29.9	1.23	0.71	0.21	0.35	1.02	0.37	83.1	52.1	2.57	1.49	0.63	0.80	1.94	0.70	75.6	47.0	76.0	69.5
5	7.9	17.9	2.11*	0.67*	0.28*	0.33*	1.83*	0.34*	86.6	50.7	1.67*	0.53*	0.23*	0.23*	1.43*	0.30*	86.0	56.6	86.7	68.8
6	16.3	29.6	2.19*	1.29*	0.38*	0.57*	1.81*	0.72*	82.6	55.8	1.59*	0.93*	0.26*	0.37*	1.33*	0.56*	83.6	60.2	80.8	70.4
7	20.2	35.6	2.26*	1.04*	0.33*	0.36*	1.92*	0.68*	85.2	65.4	1.54*	0.71*	0.18*	0.28*	1.36*	0.43*	88.6	60.6	87.8	7.0
8	19.4	44.0	2.18*	0.94*	0.29*	0.38*	1.89*	0.57*	86.5	60.6	1.48*	0.64*	0.17*	0.28*	1.30*	0.36*	88.3	56.3	87.5	78.5
Mean..	8.0	34.6	1.88	1.00	0.40	0.44	1.48	0.56	78.7	56.0	2.22	1.22	0.56	0.56	1.66	0.66	74.8	54.1	77.0	73.7
			Samples Composited Over Maximum 4-Hour Period (Computed on 24-Hour Basis)																	
July 22	.....	.....	6.27	2.30	1.07	0.79	5.21	1.51	83.0	65.7	5.38	1.97	0.69	0.48	4.68	1.49	87.1	75.6	.....	.....
27	.....	.....	6.10	2.73	1.50	1.23	4.60	1.51	75.4	55.3	3.47	1.55	0.64	0.59	2.83	0.96	81.5	61.9	.....	.....
Mean..	.....	.....	6.19	2.52	1.29	1.01	4.91	1.51	79.3	59.9	4.43	1.76	0.67	0.54	3.76	1.23	84.9	69.9	.....	.....

*Flows used for computing these values based upon % of settled sewage flow going to each filter. Analysis of primary settling tank effluent used in place of applied sewage in computing applied values.


B.O.D. APPLIED - POUNDS PER CUBIC YARD
0
1
2
3
4
5
1
2
3


B.O.D. APPLIED - POUNDS PER CUBIC YARD
0
1
2
3
4
5

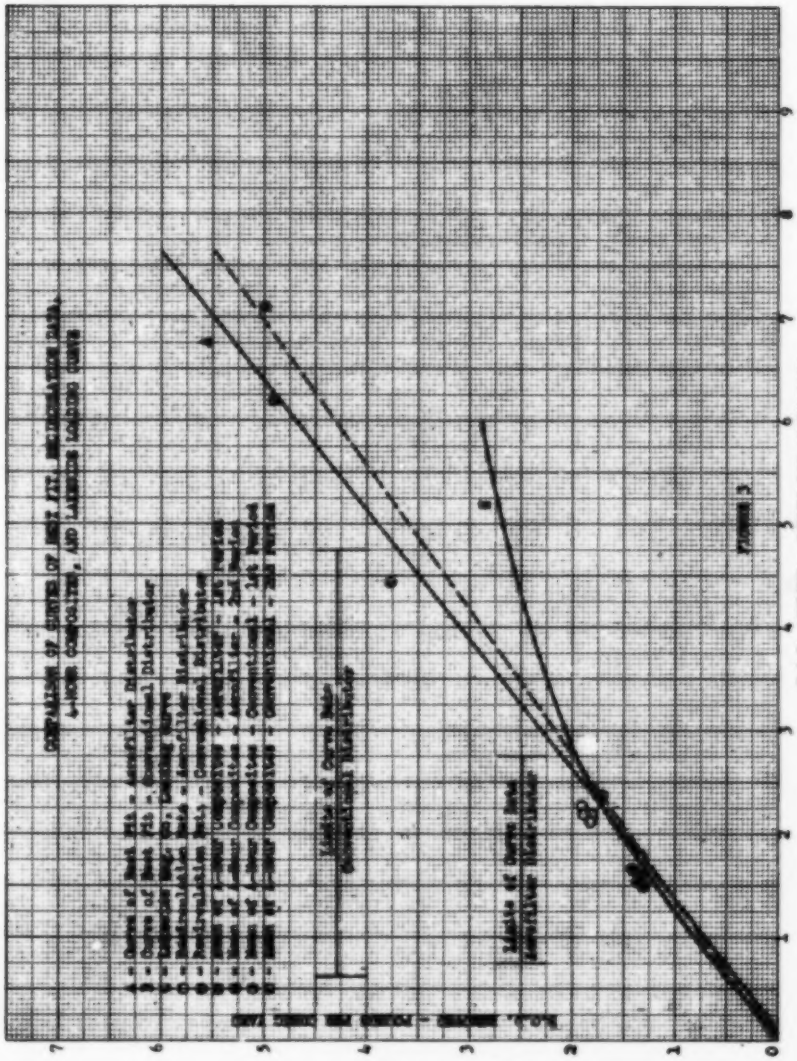
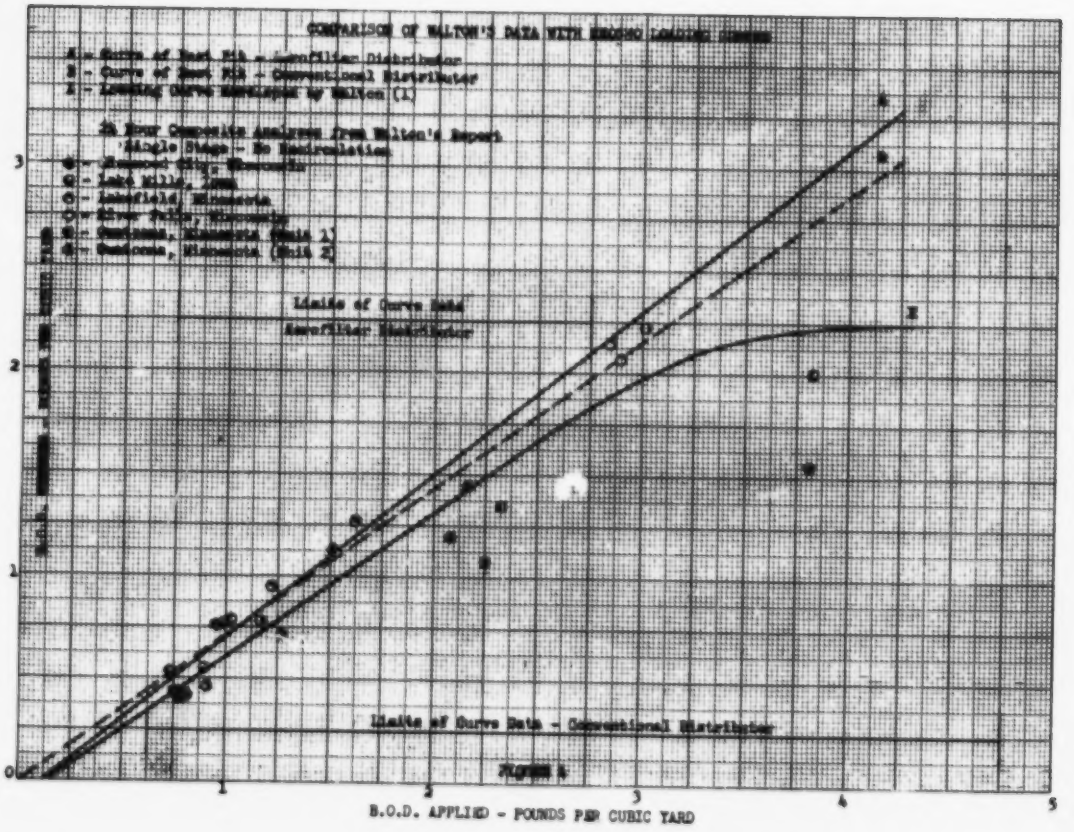


FIGURE 13


COMPARISON OF WALTON'S DATA WITH BROUND LOADING CURVES
A - Curve of Best Fit - Rawnsley Distributor
B - Curve of Best Fit - Conventional Distributor
C - Loading Curve Recommended by Walton (1)
24 Hour Composite Analyses from Walton's Report
"Middle Stage - No Recirculation"
e - Kenosha, Wisconsin
f - Lake Mills, Iowa
g - Litchfield, Minnesota
h - Olivia, Minnesota
i - Owatonna, Minnesota (Unit 1)
j - Owatonna, Minnesota (Unit 2)
Limits of Curve Data
Rawnsley Distributor
Limits of Curve Data - Conventional Distributor
FIGURE 4
B.O.D. APPLIED - POUNDS PER CUBIC YARD

tions made over a relatively short period are too few to develop an accurate loading curve. Many additional observations made under a variety of conditions should be obtained before attempting to develop a precise curve approximating all conditions. The curves of best fit presented herewith, therefore, should be used with caution. In Figures 3 and 4 the curves have been extended for comparative purposes only. Limits of the data used in developing the curves are clearly shown.

With due regard to the above, there are sufficient data to show conclusively that any difference in efficiency of the two filters within the range of loadings studied is not significant.

The limited data obtained during the four days when recirculation was employed indicate that a loading curve developed for parallel recirculation would be above and approximately parallel to the curves developed when no recirculation was employed. This indicates an increase in efficiency and was to be expected. No attempt was made to develop a curve because of the paucity of data.

Too little is known of the relationship of 4-hour composite samples to 24-hour composite samples to understand their significance. It is interesting to note that they lie very close to the curve of best fit developed from 24-hour composite samples, but whether the straight-line trend continues to the maximum 4-hour loadings or breaks before reaching them is merely a matter for conjecture. An attempt was made to study the trend of the load during the 4-hour period of maximum load. Unfortunately, time and laboratory facilities did not permit the completion of this study.

In comparing the curves developed to that used by the Lakeside Engineering Corporation, it will be noted that the Lakeside curve is parallel to, but slightly higher than, the curves of best fit up to a loading of about 2.0 pounds per cubic yard, where it breaks sharply. While there is no evidence of a break in the Neosho results up to loadings in excess of 2.5 pounds, it should be pointed out that these studies were made on a single sewage having a high percentage of milk wastes and on filters 8 feet in depth. The Lakeside loading curve was developed from results obtained from many plants. In all probability the characteristics of the sewage were different as well as the filter depths and, possibly, operating conditions. This does not detract from the value of the Neosho study but may possibly explain the absence of a break in the straight-line trend of the Neosho data.

On Fig. 4 is shown a loading curve developed by Walton in his high-rate sewage filter study compared with the two curves based on the results of the Neosho Study. Walton's curve, showing loadings and removals based on a unit volume of filter media rather than a unit surface area was included in the original report for comparative purposes, but omitted from the final published report due to lack of space. Individual

observations of those results obtained by Walton where no recirculation was employed have been indicated. No data could be found in the Walton report which could be directly compared with the results obtained during the four days of the Neosho study when recirculation was employed.

Suspended Solids Determinations: The detailed results of the suspended solids determinations will be found in Appendix B. The results have also been summarized, for convenience, in various forms in Tables 1 and 2. Table 1 gives the total daily pounds of suspended solids for the various sampling points; Table 2, the filter loadings expressed in pounds per cubic yard, the percentage removal by the primary tank, and the overall percentage removal.

In plotting the suspended solids results, the individual determinations were so scattered that, except for a general trend which indicated greater removals with increased load, an exact correlation was not possible. The variation and trend of the data collected definitely suggest a low direct correlation. This may be explained by the absorption of soluble and colloidal organic matter from the applied sewage and its conversion by the zoogleal masses in the filter to organized suspended matter. This regular production of organized suspended matter, part of which is more or less continuously unloaded, affects the suspended solids balance and gives scattered results. This prevents the determination of an accurate solids removal trend for the filter alone on a limited number of observations.

As with the B.O.D. determinations, there appears to be no significant difference in the production and removal of suspended solids by the two filters.

Nitrogen Determinations: Detailed results of the various nitrogen determinations will be found in Appendix B. Table 3 gives the daily pounds of the various nitrogen constituents for convenience.

Nitrification during the first period was considered to be good in both filters. This is believed due to two factors: First, to the light load encountered during this period; and second, to the use of filters 8 feet in depth. During the second period, however, nitrification did not occur to any significant degree, although there were several days when the load applied to the filter was less than the maximum loadings encountered during the first period. It is believed that nitrification did not occur under these low loads because the period of low loading did not last long enough for the nitrifying bacteria to develop in sufficient numbers.

In studying nitrogen transformations from the data, attempts were made to correlate nitrification with B.O.D. and total organic nitrogen removal. The correlation between these parameters proved to be very poor. A study of the correlation between the quantity of B.O.D.

TABLE 3
POUNDS OF NITROGEN CONSTITUENTS

Date 1945	Raw Sewage		Applied to Aerofilter Dist.				Aerofilter Dist. Settled Effluent				Applied Conventional Dist.				Conventional Dist. Settled Effluent				Plant Effluent	
	T.O.N.[1]	Amm. N.	T.O.N.	Amm. N.	$NO_2N.$	$NO_3N.$	T.O.N.	Amm. N.	$NO_2N.$	$NO_3N.$	T.O.N.	Amm. N.	$NO_2N.$	$NO_3N.$	T.O.N.	Amm. N.	$NO_2N.$	$NO_3N.$	$NO_2N.$	$NO_3N.$
							Samples Composited Over 24-Hour Period													
Mar. 19	105.64	25.55	64.49	24.80	5.79	13.23	41.34	19.02	3.31	28.11	53.21	20.47	4.78	10.92	34.11	13.64	3.41	23.20	7.55	48.29
20	88.62	17.15	51.51	9.97	6.65	16.62	25.75	3.74	4.15	43.20	37.12	7.18	4.79	11.97	16.76	1.50	2.99	35.92	7.15	57.18
21	86.84	27.29	42.83	9.37	6.69	0	16.73	2.68	3.35	33.46	36.56	8.00	5.71	0	14.28	1.14	1.14	28.56	6.20	74.43
24	168.44	60.16	84.38	33.15	3.39	0	39.93	18.08	3.01	37.67	65.34	25.67	2.63	0	32.67	14.00	2.33	35.01	7.35	80.21
25	181.33	71.96	92.33	37.47	Trace	0	47.69	21.29	5.96	34.07	64.03	25.85	Trace	0	36.42	14.69	3.52	23.50	8.63	57.56
26	115.00	68.46	79.69	47.82	Trace	0	35.86	15.94	3.59	31.88	57.22	34.33	Trace	0	22.32	11.44	2.57	22.89	6.85	54.76
27	192.49	76.49	88.34	39.51	Trace	0	46.13	17.24	3.95	21.55	68.45	30.61	Trace	0	31.16	13.91	3.06	16.69	11.47	25.50
28	159.88	71.49	86.15	49.03	Trace	0	31.52	12.61	4.20	23.81	73.73	41.96	Trace	0	33.57	11.99	3.30	19.18	9.10	77.99
29	147.47	58.40	97.21	49.43	Trace	0	37.07	32.95	4.94	24.72	75.08	38.17	Trace	0	30.54	12.72	3.82	19.09	13.14	29.20
30	140.57	50.20	85.19	40.19	0.72	Trace	45.01	40.19	4.42	48.22	66.86	31.54	0.57	Trace	35.32	23.97	3.78	37.84	8.61	85.06
Apr. 1	146.03	29.80	97.52	101.76	0.59	Trace	42.40	25.44	3.39	33.92	73.84	77.05	0.45	Trace	31.46	19.26	2.57	25.68	6.71	59.60
2	172.13	83.96	86.14	39.51	0.47	Trace	30.82	28.45	3.40	39.51	66.40	30.46	0.37	Trace	27.41	19.49	2.74	30.46	7.70	69.97
3	257.68	134.21	106.70	57.16	Trace	Trace	34.30	33.53	4.95	38.11	81.20	43.50	Trace	Trace	24.36	23.20	3.48	29.00	8.72	69.79
4	191.21	80.23	76.57	33.13	0.06	Trace	41.23	26.50	4.42	36.81	62.49	27.04	0.05	Trace	.....	19.22*	3.30*	30.05*	8.02	66.86
5	153.99	88.84	86.81	51.57	0.06	Trace	42.98	30.94	4.30	32.66	62.74	37.27	0.06	Trace	32.93	22.36	2.80	24.85	7.40	59.23
7	185.93	66.41	106.62	37.28	Trace	Trace	31.32	26.84	4.47	25.35	83.30	29.13	Trace	Trace	30.87	20.97	2.91	20.97	6.64	45.16
8	187.53	68.44	95.19	42.91	Trace	Trace	39.01	31.21	4.68	24.97	71.80	32.37	Trace	Trace	31.19	22.36	3.77	17.66	8.21	43.80
9	246.53	110.29	112.93	51.33	0.12	Trace	59.40	32.27	5.87	35.20	86.88	39.49	0.10	Trace	41.18	24.82	5.08	29.34	11.68	64.88
10	229.05	88.10	107.68	43.65	Trace	Trace	63.30	29.10	4.37	29.10	78.58	31.86	Trace	Trace	28.14	19.11	3.45	22.30	8.18	55.37
11	199.21	89.96	108.87	44.14	Trace	Trace	.....	32.37	4.05	44.14	81.33	32.97	Trace	Trace	.....	23.08	2.75	29.67	7.07	77.11
Mean..	167.78	68.37	87.86	42.16	.....	.....	39.67	24.02	4.24	33.32	67.31	32.25	.....	.....	29.71	16.51	3.13	25.88	8.32	60.15
					Samples Composited Over Maximum 4-Hour Period (Pounds of Constituents Computed on 24-Hour Basis)															
Mar. 26	.....	101.68	98.14	61.34	.....	.....	46.44	17.53	.....	.....	66.47	41.54	.....	.....	24.93	11.87	.....	.....	.....	.....
28	156.12	76.16	73.84	42.02	.....	.....	31.82	12.01	.....	.....	78.44	44.64	.....	.....	31.88	12.75	.....	.....	.....	.....
Apr. 4	209.58	99.13	124.74	48.60	.....	.....	47.79	25.92	.....	.....	95.10	37.05	.....	.....	32.73	21.00	.....	.....	.....	.....
7	211.59	103.57	119.02	51.01	.....	.....	42.51	30.60	.....	.....	83.90	35.96	.....	.....	31.76	22.77	.....	.....	.....	.....
10	223.99	70.00	127.30	40.54	0.61	Trace	65.67	27.57	3.24	37.30	91.51	29.14	0.44	Trace	29.14	19.82	2.33	24.48	.....	.....
Mean..	200.32	90.11	108.61	48.70	.....	.....	46.85	22.73	.....	.....	83.08	37.67	.....	.....	30.09	17.64	.....	.....	.....	.....

*Regular sample broken. 24-hour filter effluent sample used after mixing and settling 1 hour. Omitted from averages.
[1]Total organic nitrogen.

TABLE 3—Continued

POUNDS OF NITROGEN CONSTITUENTS

Date 1945	Raw Sewage		Applied to Aerofilter Dist.				Aerofilter Dist. Settled Effluent				Applied Conventional Dist.				Conventional Dist. Settled Effluent				
	T.O.N.	Amm. N.	T.O.N.	Amm. N.	$NO_2N.$	$NO_3N.$	T.O.N.	Amm. N.	$NO_2N.$	$NO_3N.$	T.O.N.	Amm. N.	$NO_2N.$	$NO_3N.$	T.O.N.	Amm. N.	$NO_2N.$	$NO_3N.$	
July 12	216.73	44.50	85.62	30.58	0.10	1.09	64.06	13.59	1.63	9.79	101.29	36.17	0.12	1.29	79.26	24.12	2.33	9.65	Plant Effluent Not Computed this Period.
13	262.04	71.99	98.96	45.64	0.10	0.26	71.21	28.69	0.89	1.04	119.57	55.14	0.12	0.32	82.08	31.51	0.80	0.95	
14	215.13	71.47	111.21	54.02	0.10	0.25	70.67	46.39	1.99	0.76	138.94	67.48	0.12	0.32	105.12	63.51	0.12	0.64	
15	225.70	100.76	94.58	50.37	0.04	0.24	74.67	56.30	0.82	1.66	119.84	63.82	0.06	0.30	96.56	71.33	1.41	0.60	
16	200.87	153.36	113.25	80.15	0.02	0.25	91.30	67.82	0.54	0.62	141.19	99.92	0.02	0.31	112.14	69.17	1.06	0.46	
18	223.87	121.96	93.62	48.54	0.01	0.11	75.50	48.54	1.01	0.65	141.63	73.43	0.02	0.16	112.83	69.35	0.92	0.82	
19	289.91	132.38	86.09	38.54	0.004	0.04	64.74	46.24	1.21	1.85	209.65	93.85	0.01	0.09	144.52	89.15	0.23	0.56	
20	286.71	178.68	84.33	60.23	0.01	0	70.47	51.63	2.47	2.24	185.07	132.19	0.03	0	151.73	113.31	0.83	0	
21	289.00	223.16	180.78	122.98	0	0	143.96	138.35	0.10	0	147.28	100.19	0	0	119.41	93.93	0.16	0	
22	255.30	168.33	152.41	89.21	0	0	108.84	89.21	1.03	0.74	135.16	79.12	0	0	106.35	79.12	1.24	1.45	
24	280.75	116.41	145.62	83.88	0.10	0	133.88	67.11	0.11	0	106.98	61.63	0.07	0	96.63	49.30	0.54	0.37	
25	243.03	181.36	135.35	102.66	0	0	96.66	71.07	0.79	0	103.77	78.70	0	0	73.74	66.60	2.27	2.18	
26	232.04	164.37	129.37	95.24	0	0	98.02	87.30	0.90	0	93.90	69.13	0	0	74.20	51.85	1.80	1.73	
27	237.06	169.33	134.67	81.82	0.02	0	102.06	65.21	0.51	0	98.45	59.59	0.02	0	75.56	53.63	3.13	1.31	
28	261.97	134.31	139.67	75.34	0.03	0	105.47	67.80	1.42	0.75	109.34	58.98	0.02	0	80.92	53.08	3.39	1.77	
30	282.53	161.54	84.22	53.79	0.04	0	69.39	49.31	0.95	0.18	168.71	107.75	0.07	0	123.73	98.77	0.22	0.18	
31	294.44	156.34	78.51	48.69	0	0	65.00	44.63	1.83	0.32	173.58	107.65	0	0	127.56	98.68	0.79	0	
Aug. 1	226.83	152.58	63.63	45.23	0	0	49.38	26.39	2.26	0.38	151.00	107.35	0	0	98.94	80.51	0.56	0.18	
2	244.98	145.82	67.65	39.37	0	0	48.50	32.21	1.70	0.04	162.02	94.30	0	0	111.87	85.72	0.43	0	
3	248.64	190.87	77.37	65.77	0	0	65.61	57.58	1.95	0	162.12	137.83	0	0	126.37	120.60	0.54	0	
5	246.86	192.67	226.05	158.96	0.28	0	174.72	145.71	8.28	0.79	179.04	125.57	0.22	0	130.70	125.57	7.59	0.21	
6	293.97	236.60	257.53	210.77	0	0	204.58	182.66	8.43	0.86	193.45	152.40	0	0	151.39	142.24	5.33	0.41	
7	285.06	217.12	266.21	226.37	0	0	220.03	211.28	12.83	0.91	181.3[illegible]	154.24	0	0	144.57	154.24	6.68	0.93	
8	218.97	148.54	220.13	180.44	0	0	168.41	135.33	9.77	1.05	148.98	122.11	0	0	111.32	91.58	5.60	0.81	
Mean	253.97	151.39	130.73	87.01	0.04	0.09	101.55	76.26	2.64	1.01	144.68	93.27	0.04	0.12	109.90	82.37	1.99	1.05	

NOTE—No nitrogen determinations were made on 4-hour composites collected during this period.

removed and the quantity of nitrite and nitrate nitrogen produced per 100 pounds of B.O.D. removed was then made. The data for the first period of study gave the relatively high correlation coefficients of −.76 and −.75 for Filter A and B respectively. These negative correlation coefficients indicate good inverse correlation between these parameters. During the second period of study with higher loadings nitrification was negligible. It is true that some nitrites and nitrates were usually found in the effluent during the second period but the quantity produced per 100 pounds of B.O.D. removed was very low indeed as shown in the following table.

Filter	Pounds of B.O.D. Removed Per Cubic Yard						Pounds of Nitrogen as Nitric Oxides* Produced per 100 lbs. B.O.D. Removed					
	Max.		Min.		Mean		Min.		Max.		Mean	
	I	II	I	II	I	II	I	II	I	II	I	II
A	1.05	2.16	0.50	0.70	0.80	1.48	4.24	0.03	14.82	1.76	7.10	0.38
B	0.83	3.34	0.39	0.96	0.63	1.65	3.99	0.01	15.07	1.77	7.02	0.32

I = 1st period − 20 daily observations
II = 2nd period − 23 daily observations
* = NO_2 plus NO_3 Nitrogen

These data show the great differences in nitrification per 100 pounds of B.O.D. removed that occurred because of the increased load from the first to the second period of study. It will be noted that during the first period the quantity of nitrogen oxides formed on the average was about 20 times as great as during the second period. This reduction in nitrification occurred in spite of the fact that the mean sewage temperature of 72.4° F. during the second period was about 13 degrees higher, and consequently was more favorable for nitrification than the first period. This indicates that the load is a very important factor in nitrification in high rate filters and that there is a critical load above which nitrification will be negligible.

The curves of best fit representing the inverse correlation between these parameters for the first period are as follows:

For Filter A, $y = -.055\ X + 1.19$
For Filter B, $y = -.038\ X + 0.89$

Where X = the quantity of nitrite plus nitrate nitrogen in pounds produced per 100 pounds of B.O.D. removed, and

y = the quantity of B.O.D. in pounds removed per cubic yard

When X is equal to zero in these equations, y is equal to 1.19 and 0.89 pounds of B.O.D. removed per cu. yard for filter A and B respectively. These values represent the approximate limits in quantity of B.O.D. removed above which the rate of nitrification per 100 pounds of B.O.D. removed would be negligible at 60° F. The above limits can be converted into terms of applied B.O.D. load from the correlation that has already been demonstrated for these parameters. Thus for this temperature range, from figures 1 and 2, it can be concluded that good nitrification rates can not be expected at filter loadings above about 1.5 lbs. of B.O.D. per cubic yard for Filter A, and 1.1 pounds for Filter B. About half of the filter loadings during the second period of the study were above these critical values and the data collected demonstrated negligible nitrification. It can be concluded therefore that for summer temperatures the critical B.O.D. loading above which nitrification becomes negligible is somewhat below the mean load given these filters during the second period.

These data also suggest a slight advantage in nitrification rates for the Aerofilter distributor below the critical applied B.O.D. load. Accordingly, the critical applied B.O.D. load above which nitrification is negligible, is about 0.4 pounds higher per cu. yard for the Aerofilter distributor than for the conventional distributor. However, above this critical applied B.O.D. load the Aerofilter showed no advantage in nitrification.

Miscellaneous Determinations: The dissolved oxygen content of the two filter and plant effluents during the first period are given in Appendix C. With few exceptions the results varied from 5.0 to 7.0 p.p.m., indicating an oxygen saturation of 65 to 70 per cent at the temperatures noted. All analyses were made on grab samples taken during the day. Dissolved oxygen determinations of night flows would have had little significance, because there was considerable infiltration and night plant loadings were light.

During the second period, the special study to determine the effectiveness of the "rain-like" spray to increase the dissolved oxygen content of the applied sewage was made as described earlier. The data obtained are shown in Table 4. It will be noted that the average dissolved oxygen found in the applied sewage taken from the distribution box was 2.66 p.p.m. and that this was increased to 4.05 p.p.m. by the conventional distributor and to 4.92 p.p.m. by the "rain-like" spray of the Aerofilter distributor. The mean 15 minute B.O.D. of the applied sewage was 0.61 p.p.m. The mean dissolved oxygen in the filter effluents was 4.10 and 4.09 p.p.m. for the filters with the Aerofilter and conventional distributor respectively. It must be concluded from these data that the dissolved oxygen in the applied sewage was not increased significantly as far as its effect on biological oxidation is concerned by the Aerofilter

TABLE 4

A STUDY OF THE DISSOLVED OXYGEN BALANCE ON HIGH RATE FILTERS AT NEOSHO, MISSOURI

Date 1945	Sewage temperature	Cumulative B.O.D. of applied sewage for indicated time in minutes at sewage temperature, p.p.m.				Applied sewage from distribution box		Filter with Aerofilter distributor				Filter with conventional distributor				Change in D.O. from filter surface to filter effluent, p.p.m.	
								Sewage caught at filter surface		Filter effluent		Sewage caught at filter surface		Filter effluent			
	°C.	15 min.	30 min.	45 min.	1.0 hour	Time	D.O. p.p.m.	Time	D.O. p.p.m.	Time	D.O. p.p.m.	Time	D.O. p.p.m.	Time	D.O. p.p.m.	Aerofilter distr.	Conventional distr.
7-29	24	0.42	1.50	2.42	.....	6:40 P.M.	2.37	7:37 P.M.	5.25	8:00 P.M.	3.47	7:17 P.M.	3.93	7:45 P.M.	4.11	−1.78	+0.18
	.....	.....	.....	.....	.....	8:10 P.M.	2.91	.....	.....	.....	.....	.....	.....	8:15 P.M.	3.97	.....	+ .04
7-30	23	.47	1.28	1.97	2.77	11:00 A.M.	2.32	10:50 A.M.	4.67	.....	.....	10:55 A.M.	4.01	.....	.....	− .47	− .41
	.....	.....	.....	.....	.....	11:05 A.M.	2.25	12:32 P.M.	4.60	12:37 P.M.	4.20	12:52 P.M.	3.78	12:57 P.M.	3.60	− .40	− .18
8-8	24.8	.94	1.27	1.92	2.59	3:30 P.M.	3.43	4:08 P.M.	5.14	4:04 P.M.	4.63	3:41 P.M.	4.47	3:45 P.M.	4.60	− .51	+ .22
Mean	.....	0.61	1.35	2.10	2.68	.....	2.66	.....	4.92	.....	4.10	.....	4.05	.....	4.09	.....	.....

Each D. O. value shown is the mean of 2 or 3 individual titrations.
All samples collected for D. O. contained 10 ml. of 10% $CuSO_4$ sol. per liter when collected to inhibit biochemical oxidation.

	Final effluent	
	Time	D.O. p.p.m.
7-30	1:25 P.M.	2.26
8-8	4:17	3.59

"rain-like" spray distribution under the sewage and filter conditions encountered at Neosho. It is possible that the additional dissolved oxygen applied by the Aerofilter "rain-like" spray would be significant with stale sewage in warm climates.

A comparison of the mean dissolved oxygen data for the two periods of study follows:

Period	Mean Sewage Temperature C°	Mean Dissolved Oxygen p.p.m.		
		Filter Effluent		Final Effluent
		A Aerofilter Distributor	B Conventional Distributor	
March-April	16.5	6.47	6.87	5.76
July-August	23.9	4.10	4.09	2.92

These data indicate no advantage due to "rain-like" spray distribution in the dissolved oxygen in the filter effluent at either period.

The analyses of digester supernatant samples are not given in tabular form. The pH of these samples varied from 6.5 to 7.3, and the B.O.D. from 396 to 580 p.p.m. The results of the nine samples analyzed during the study were in close agreement and indicated good digester operation. Although the supernatant was generally returned over a 20 to 30 minute period every other day, the data suggest that the plant operation was not materially affected by digester operation.

Two attempts were made to follow a shock load through the plant by taking grab samples when an unusually heavy milk waste load appeared. In one instance the oxygen was depleted from both dilutions of the raw sewage sample, indicating a raw sewage strength of over 3000 p.p.m. However, such extreme loads lasted only a few minutes and dilution in the primary tanks reduced the strength of the applied load to about 500 p.p.m. The above condition did not appear to last over 30 minutes and did not materially affect the 24-hour composite sample.

Preliminary observations indicated that there was no significant difference in the biology of the two filters.

Distribution data, computed as suggested by Walton[1] will be found in Table 5. Although these terms were devised as a means of comparing the distribution characteristics of different distributors, they have not been generally adopted and there are insufficient data to determine the relationship of relatively poor coefficients to filter efficiency. No attempt will be made, therefore, to explain the significance of these coefficients

in this report. It should be obvious, however, that if distribution on sewage filters is important, the results obtained from a filter having good distribution will be superior to those from a filter having poor distribution. As the degree of difference necessary to affect filter efficiency has not been definitely determined, it cannot be stated that any of the distribution data given in Table 5 have affected the results of this study.

TABLE 5

DISTRIBUTION DATA

First Period

	Aerofilter		Conventional	
Dosing rate g.p.m.	1200.	1800.	1200.	1800.
Coefficient of Area*	0.995	0.995	0.925	0.925
Coefficient of Distribution*,**	1.46	1.54	1.68	1.84
Dosing Ratio*	1.82	1.65	1.54	1.48
Mean Depth (1/32 inches) = M.**	18.9	19.8	25.3	16.8
Standard Dev. (1/32 inches) = S.D.†	±5.91	±5.95	±10.49	±6.92
Coefficient of variation = $\frac{\text{S.D.x 100}}{\text{M}}$†	31.29	30.08	41.46	41.21

NOTE—Only ¼ of the arms of each filter were used during the first period and the distribution data were collected under these conditions.

Second Period

	Aerofilter		Conventional
Number of arms used	6	8	4
Coefficient of Area*	0.995	0.995	0.995
Coefficient of Distribution*, **	1.34	1.27	1.36
Dosing Ratio*	1.50	1.35	1.65
Mean Depth (1/32 inches) = M**	12.4	18.9	22.2
Standard Deviation (1/32 inches) = S.D.†	±3.27	±4.49	±6.55
Coefficient of Variation = $\frac{\text{S.D. x 100}}{\text{M}}$†	26.37	23.74	29.52

NOTE—For certain periods during this portion of the study 6 of the 8 Aerofilter arms were used, at others 8 arms.

*These terms were developed by Walton[1], who defined them as follows:

Coefficient of Area—The Coefficient of Area is the ratio of that filter surface receiving sewage, to the total filter surface area.

Coefficient of Distribution—The Coefficient of Distribution is the sum of those filter areas, expressed in per cent of the filter surface receiving sewage, on which the flow deviates from the average dosing rate by 100% or more, 75% or more, 50% or more, 25% or more, and 0% or more, this sum divided by 100.

Dosing Ratio—The Dosing Ratio is the maximum dosing rate on any unit area of the filter, divided by the average dosing rate on that area of the filter receiving sewage.

**On the basis of entire filter area and the assumption of equal depth for entire ring.

†Standard Deviation and coefficient of variation are both based on departure from mean depth (M).

The Coefficients of Area as given in Table 5 indicate that there was no difference in the coefficients for either filter for the two flow ranges encountered during the second period. However, there was a rather marked difference in the coefficients of the two filters during the first period. Essentially, these coefficients mean that 99.5% of the area of the Aerofilter and 92.5% of the conventional filter was effectively dosed. This would indicate a slightly higher loading on that area of the filter with the conventional distributor which was receiving sewage. No attempt has been made to compensate for this in the tables indicating filter loadings. For one thing, it is possible that dispersion of the sewage below the filter surface may be such that virtually the entire filter area is effectively utilized a short distance below the surface.

The Coefficients of Distribution given in Table 5 indicate that throughout the study the distribution on the Aerofilter was somewhat better than that on the conventional filter. A coefficient of 1.0 would indicate that the deviation in any concentric 6-inch ring varied no more than 25% from the average over the entire filter. The greater the deviation and the greater the area of the ring, the higher the coefficient. As only limited data are available concerning the Coefficient of Distribution as it relates to filter efficiency, the only conclusion which can be drawn from the above is that previously indicated; i.e., that the sewage distribution on the Aerofilter is slightly better than on the conventional filter.

These distribution coefficients have no bearing on the momentary rate of application of sewage to a unit area. Obviously, the momentary rate of application to a unit area of the filter having a conventional distributor was far greater than that applied to the Aerofilter.

The Dosing Ratios given in Table 5 indicate that the maximum dosing rate on a unit area of the conventional filter, compared to the average dosing rate over the entire filter, was somewhat less than on the Aerofilter for both flow ranges checked during the first period. However, during the second period the reverse was true. Here again, the significance of this difference and its effect on filter efficiency cannot be fully determined until additional data are available.

In addition to the procedures suggested by Walton, Table 5 includes the standard deviation and coefficient of variation of distribution from the mean depth as computed by standard statistical procedure. Both the procedures suggested by Walton and the standard statistical methods are cumbersome and probably much more refined than are needed to correlate distribution with filter efficiency. Further, they are too complicated to be of practical use to the small operator. Finally, a considerable volume of additional data must be accumulated and analyzed before the various coefficients can be correlated with efficiency and their significance fully understood.

CONCLUSIONS

1. Although the sewage distribution on the Aerofilter was slightly more uniform than on the filter with the conventional distributor, within the limits of the data there was no significant difference in the efficiency of the two filters either as regards B.O.D., suspended solids, or nitrogen removals or transformations.

2. Within the load limits studied; i.e., up to about 2½ pounds of B.O.D. per cu. yd., there appeared to be no break in the straight line relationship between B.O.D. loadings and removals.

3. The study of nitrogen transformations indicated that both filters gave nitrification in the order of 3 to 6 p.p.m. with applied B.O.D. loads up to a critical load above which nitrification was negligible. Below this critical load there was an inverse correlation between the load and the nitrification expressed as pounds of nitrogen oxides produced per 100 pounds of B.O.D. removed. The aerofilter distributor showed a slight advantage over the conventional distributor in nitrification below the critical load. The critical applied load was apparently between 1.0 and 1.5 pounds of B.O.D. per cubic yard for these filters.

4. Dissolved oxygen studies on the distributor discharges and filter effluents failed to indicate any biochemical advantage for "rain-like" spray sewage application at Neosho, Missouri.

APPENDIX A

FLOW AND TEMPERATURE DATA—1ST RUN

All Flows Expressed in Million Gallons (No Recirculation)

Date 1945	Raw Sewage Flow	Flow to Filter A	Dosing Rate A (MGAD)	Flow to Filter B	Dosing Rate B (MGAD)	% Flow to Filter A	Sewage Temp. F°	Air Temp. F°
March 19	1.8116	0.9926	18.2	0.8190	15.0	54.79	58	58
20	1.7160	0.9973	18.3	0.7187	13.2	58.12	57	46
21	1.4892	0.8035	14.7	0.6857	12.6	53.95	58	47
24	1.6048	0.9044	16.6	0.7004	12.8	56.36	60	65
25	1.7276	1.0224	18.7	0.7052	12.9	59.18	58	60
26	1.6436	0.9567	17.5	0.6869	12.6	58.21	56	61
27	1.5304	0.8624	15.8	0.6680	12.2	56.35	59	69
28	1.5604	0.8408	15.4	0.7196	13.2	53.89	60	67
29	1.7528	0.9890	18.1	0.7638	14.0	56.43	61	58
30	1.7220	0.9648	17.7	0.7572	13.9	56.03	59	53
April 1	1.7888	1.0180	18.7	0.7708	14.1	56.91	60	58
2	1.6800	0.9487	17.4	0.7313	13.4	56.47	60	57
3	1.6112	0.9149	16.8	0.6963	12.8	56.79	61	64
4	1.6052	0.8838	16.2	0.7214	13.2	55.06	58	39
5	1.7776	1.0318	18.9	0.7458	13.7	58.05	60	43
7	1.5944	0.8951	16.4	0.6093	12.8	56.14	60	55
8	1.6432	0.9367	17.2	0.7065	13.0	57.00	61	62
9	1.5576	0.8803	16.1	0.6773	12.4	56.52	63	68
10	1.5108	0.8734	16.0	0.6374	11.7	57.81	60	67
11	1.5428	0.8831	16.2	0.6597	12.1	57.24	63	66
Mean	1.6435	0.9300	17.1	0.7135	13.1	56.59	59.6	58.2
		Flow	(24-Hour Rate)	During 4-Hour Peak Periods*				
March 26	1.7438	1.0519	19.3	0.7124	13.1	59.62		
28	1.5238	0.7207	13.2	0.7655	14.0	48.40		
April 4	1.7000	0.9724	17.8	0.7414	13.6	56.74		
7	1.7763	1.0206	18.7	0.7194	13.2	58.65		
10	1.6806	0.9734	17.8	0.6998	12.8	58.18		
Mean	1.6849	0.9478	17.4	0.7277	13.3	56.25		

*Total flow does not equal sum of flows to 2 filters because of time lag in sample collection and flow measurement periods.

Note! Aerofilter designated as Filter A. Filter with conventional distributor as Filter B.

APPENDIX A—Continued

FLOW AND TEMPERATURE DATA—2ND RUN

All Flows Expressed in Million Gallons

Date 1945	Raw Sewage Flow	Flow to Filter A	Dosing Rate A (MGAD)	Flow to Filter B	Dosing Rate B (MGAD)	% Flow to Filter A	Sewage Temp. F°	Air Temp. F°
July 12	1.7808	0.8158	15.0	0.9650	17.7	45.81	70	80
13	1.7284	0.7828	14.4	0.9456	17.3	45.29	70	75
14	1.7160	0.7629	14.0	0.9531	17.5	44.46	70	76
15	1.6128	0.7114	13.0	0.9014	16.5	44.11	70	75
16	1.6628	0.7401	13.6	0.9227	16.9	44.51	71	74
18	1.6268	0.6474	11.9	0.9794	18.0	39.80	70	77
19	1.5892	0.4626	8.5	1.1266	20.7	29.11	72	78
20	1.6500	0.5165	9.5	1.1335	20.8	31.30	72	85
21	1.6744	0.9227	16.9	0.7517	13.8	55.11	75	97
22	1.6840	0.8925	16.4	0.7915	14.5	53.00	74	87
24	1.7468	1.0070	18.5	0.7398	13.6	57.65	72	88
25	1.6748	0.9480	17.4	0.7268	13.3	56.60	71	82
26	1.6444	0.9528	17.5	0.6916	12.7	57.94	70	81
27	1.6940	0.9786	17.9	0.7154	13.1	57.77	69	75
28	1.6124	0.9044	16.6	0.7080	13.0	56.09	69	74
30	1.6160	0.5381	9.9	1.0779	19.8	33.30	68	78
31	1.5640	0.4871	8.9	1.0769	19.7	31.14	70	80
August 1	1.5264	0.4525	8.3	1.0739	19.7	29.64	74	87
2	1.4588	0.4297	7.9	1.0291	18.9	29.46	76	85
3	1.5276	0.4935	9.0	1.0341	19.0	32.31	78	84
5	1.4456	1.5902*	29.2*	1.2562*	23.0*	55.87	81	88
6	1.7752	1.6868*	30.9*	1.2197*	22.4*	58.04	74	76
7	1.533	1.8117*	33.2*	1.2344*	22.6*	59.48	75	78
8	1.4860	1.8051*	33.1*	1.2216*	22.4*	59.64	74	74
Mean	1.6395**	0.7223**	13.2**	0.9172**	16.8**	44.06**	72.4	80.2
	Flow (24-Hour Rate) During 4-Hour Peak Period†							
July 22	1.8287	0.9909	18.2	0.8491	15.6	53.85	.....	.....
27	1.9525	1.3118	24.1	0.7457	13.7	63.76	.....	.....
Mean	1.8906	1.1514	21.1	0.7974	14.6	60.90	.....	.....

*Includes Recirculation. Recirculation employed during last 4 days only. See next page.
**Last 4 days' results excluded from mean except for temperature.
†See note at bottom of Page 35, Appendix A.

APPENDIX A (Concluded)

FLOW AND TEMPERATURES DATA—RECIRCULATION

All Flows Expressed in Million Gallons

Date 1945	Raw Sewage Flow	Flows Including Recirculation			Settled Sewage Only		% to Filter A	Recirculation Flow	Recirculation Ratio
		Total	Filter A	Filter B	Filter A	Filter B			
August 5	1.4456	2.8464	1.5902	1.2562	0.8077	0.6379	55.87	1.4007	0.97
6	1.7752	2.9065	1.6868	1.2197	1.0303	0.7449	58.04	1.1312	0.64
7	1.5332	3.0461	1.8117	1.2344	0.9119	0.6213	59.48	1.5128	0.99
8	1.4860	3.0267	1.8051	1.2216	0.8863	0.5997	59.64	1.5407	1.04
Mean	1.5600	2.9564	1.7235	1.2330	0.9091	0.6510	58.29	1.3964	0.90

APPENDIX B
RESULTS OF ANALYTICAL DETERMINATIONS
Settleable Solids, pH, B.O.D.

Date 1945	Settleable Solids, p.p.m.					pH				5-Day B.O.D., p.p.m.							
	Raw	Settled**	Filter Effluent A	Filter Effluent B	Plant Effluent	Raw	Settled**	Supernatant		Raw	Settled	Applied	Filter Effluent		Supernatant		Plant Effluent
								Filter Effluent A	Filter Effluent B				A	B	A	B	
Mar. 19	0.6	0.4	0.7	0.6	0.4	7.1	7.1	7.4	7.4	178	103	112	69	53	41	41	33
20	0.7	0.3	0.9	0.7	0.5	7.1	7.1	7.3	7.3	149	84	81	50	40	19	21	27
21	0.5	0.2	0.6	1.1	0.2	7.1	7.1	7.3	7.3	86	57	77	57	35	24	18	24
24	1.0	0.9	0.7	0.9	0.5	7.3	7.3	7.5	7.5	136	98	94	46	50	33	31	38
25	1.0	0.2	0.7	2.0	0.3	7.3	7.3	7.1	7.0	108	86	90	42	47	35	32	33
26	2.5	1.0	0.8	0.9	0.5	7.1	7.4	7.2	7.2	108	102	94	35	43	36	27	27
27	1.7	0.3	0.8	1.2	0.1	7.9	7.3	7.2	7.5	154	83	84	42	30	32	29	30
28	0.9	0.1	1.5	1.4	0.4	7.3	7.3	7.3	7.4	107	92	97	40	42	29	32	27
29	5.0	0.1	0.8	1.3	0.5	7.1	7.1	7.3	7.3	161	124	117	48	53	36	33	27
30	1.8	0.05	0.6	1.1	0.1	7.1	7.0	7.4	7.4	79	70	75	27	28	30	31	26
Apr. 1	2.3	0.5	0.9	1.1	0.2	7.3	7.2	7.3	7.3	97	64	79	34	37	23	19	28
2	3.1	0.5	1.4	1.3	0.2	7.3	7.3	7.3	7.3	142	109	115	58	44	34	33	33
3	2.9	0.2	0.9	1.3	0.2	7.0	7.0	7.3	7.3	220	133	127	55	60	43	35	36
4	2.4	0.7	2.0	1.4	0.1	7.1	7.0	7.0	7.1*	145	113	115	53	58	36	26*	30
5	5.0	0.5	0.9	0.9	0.2	7.3	7.3	7.3	7.3	161	132	130	52	54	44	40	36
7	4.3	0.3	0.4	0.3	0.1	7.3	7.3	7.5	7.5	232	124	131	50	49	39	34	33
8	4.9	1.0	0.4	0.3	0.1	7.1	7.0	7.5	7.5	101	117	120	49	54	30	29	31
9	4.5	0.6	0.3	0.5	0.1	7.2	7.2	7.5	7.5	201	150	143	57	54	45	39	28
10	5.6	0.6	0.5	0.6	0.1	7.4	7.3	7.5	7.5	174	126	121	42	24	29	28	22
11	5.6	0.3	0.2	0.3	0.1	7.3	7.3	7.2	7.2	167	119	125	44	41	30	37	29
Mean	2.81	0.44	0.80	0.96	0.25	7.23	7.19	7.3	7.3	145	104	106	47.5	45.2	33.4	30.9	30.0
						Samples Composited Over Maximum 4-Hour Period											
Mar. 26	2.8	0.7	0.8	1.1	.....	7.1	7.1	7.3	7.4	243	.....	170	64	66	53	45	.....
28	0.9	0.1	.....	.....	.....	7.2	7.1	7.5	7.4	203	.....	170	56	60	52	47	.....
Apr. 6	3.6	0.5	1.9	0.9	.....	6.7	6.8	7.3	7.3	436	.....	250	Depleted	98	75	77	.....
7	4.3	1.0	0.5	0.6	.....	7.1	7.1	7.4	7.5	248	.....	205	69	71	56	50	.....
10	5.3	0.7	0.4	0.4	.....	7.1	7.1	7.5	7.5	266	.....	252	76	64	58	52	.....
Mean	3.38	0.6	0.9	0.75	.....	7.04	7.04	7.4	7.42	279.2	.....	209.4	66.0	70.8	58.8	54.2	.....

*Regular sample broken. 24-Hour composite conventional filter effluent sample mixed, settled one hour and used as replacement.
**No recirculation. Settled and applied are the same.

APPENDIX B

RESULTS OF ANALYTICAL DETERMINATIONS

pH, B.O.D. (Continued)*

Date 1945	pH				5-Day B.O.D. p.p.m.							
	Raw	Settled	Filter A Settled	Filter B Settled	Raw	Settled	Applied	Filter A Effluent	Filter B Effluent	Filter A Settled	Filter B Settled	Plant Effluent
July 12	7.5	7.3	7.6	7.6	184	108	116	35	35	21	32	35
13	7.1	7.1	7.5	7.5	252	238	229	68	82	68	88	107
14	7.1	7.1	7.5	7.5	227	242	238	82	95	67	78	72
15	7.5	7.4	7.6	7.6	205	183	184	66	79	52	61	60
16	7.1	7.3	7.5	7.5	202	229	225	79	95	65	70	70
18	7.3	7.3	7.7	7.7	203	199	200	74	88	52	67	68
19	7.5	7.5	7.7	7.7	252	182	186	60	71	38	56	57
20	8.1	7.6	7.7	7.7	222	190	177	61	63	28	45	35
21	7.9	7.5	7.7	7.7	233	215	220	90	101	56	49	69
22	7.5	7.3	7.6	7.6	218	212	232	68	84	47	40	81
24	7.6	7.3	7.7	7.6	237	219	218	81	63	68	42	60
25	7.3	7.4	7.7	7.7	216	183	200	78	61	48	33	45
26	7.3	7.5	7.7	7.8	240	234	206	78	71	46	41	45
27	7.5	7.3	7.6	7.6	182	311	229	80	69	42	36	49
28	7.3	7.3	7.6	7.6	242	197	180	62	59	34	35	41
30	7.1	7.1	7.7	7.5	253	344	233	62	95	42	77	66
31	7.1	7.3	7.7	7.6	246	189	167	50	56	45	60	40
August 1	7.2	7.3	7.7	7.6	266	279	283	70	82	35	62	50
2	7.3	7.3	7.6	7.6	465	412	385	80	125	51	111	86
3	7.2	7.3	7.6	7.6	282	226	210	63	97	36	51	68
5	7.3	7.3	7.6	7.6	240	221	119	36	27	30	31	32
6	7.2	7.3	7.7	7.7	215	180	140	57	46	31	30	41
7	7.3	7.3	7.7	7.7	262	209	133	35	37	31	24	32
8	7.2	7.3	7.7	7.6	258	208	135	48	33	28	24	32
Mean					246	225	202	65	71	44	52	56
		Samples	Composited Over		Maximum 4-Hour Period (Computed on 24-Hour Basis)							
July 22					447		535	128	80	91	69	
27					434		393	135	96	97	73	
Mean					441		464	132	88	94	71	

*No settleable solids determinations made during 2nd period.

APPENDIX B

RESULTS OF ANALYTICAL DETERMINATIONS

Suspended and Volatile Suspended Solids

All Results Expressed in Parts Per Million

Date 1945	Suspended Solids								Volatile Suspended Solids							
	Raw	Settled	Applied	Filter Effluent		Supernatant		Plant Effluent	Raw	Settled	Applied	Filter Effluent		Supernatant		Plant Effluent
				A	B	A	B					A	B	A	B	
Mar. 19	86	75	76	64	58	42	43	45*	81	65	64	60	54	36	35	40*
20	85*	57*	66*	45*	56*	26*	25*	39*	65*	42*	46*	33*	40*	17*	15*	25*
21	106*	63*	53*	48*	69*	28*	32*	30*	99*	56*	50*	40*	62*	20*	29*	28*
24	166	101	72	98	94	76	69	58	149	90	65	84	90	70	64	50
25	118	84	81	64	58	43	43	37	88	61	64	54	43	34	34	33
26	91	83	82	47	59	34	32	30	71	67	61	30	50	22	24	17
27	92	96	87	76	74	31	30	27	86	91	81	72	71	28	27	22
28	100	77	85	66	60	36	33	36	97	74	82	55	53	37	32	35
29	148	86	82	50	50	47	39	40	136	77	72	43	44	43	35	28
30	88	75	72	30	44	32	48	28	66	46	54	25	34	16	28	25
Apr. 1	148	86	82	53	50	32	48	40	126	77	72	46	44	16	28	28
2	101	.....	75	50	68	46	40	31	77	.....	56	35	59	35	36	30
3	156	78	70	60	67	37	55	28	115	56	57	49	55	22	45	18
4	136	92	82	61	48	34	79**	27	108	71	71	60	21	24	50**	18
5	112	95	81	65	51	33	27	30	96	90	70	55	46	23	19	23
7	100	77	72	78	42	41	36	26	80	62	57	67	32	31	31	20
8	110	82	93	47	64	49	35	22	88	61	75	34	48	28	25	13
9	133	104	83	40	34	18	36	9	118	95	74	39	29	16	27	8
10	187	122	96	59	55	38	47	38	153	98	83	42	43	27	35	23
11	129	92	101	76	55	48	47	28	87	72	78	62	45	34	35	19
Mean	119.7	85.5	79.5	58.5	57.8	38.7	42.2	32.2	99.8	71.1	66.6	49.2	48.2	29.3	32.65	25.2
				Samples Composited Over Maximum 4-Hour Period												
Mar. 26	188	.....	111	73	76	50	61	.....	150	.....	92	54	60	38	50	.....
28	128	.....	96	76	74	45	60	.....	116	.....	85	75	59	43	56	.....
Apr. 4	91	.....	63	76	47	50	48	.....	80	.....	43	66	30	45	33	.....
7	106	.....	90	42	57	51	40	.....	89	.....	85	30	50	36	35	.....
10	162	.....	86	82	78	89	20	.....	124	.....	70	70	64	57	19	.....
Means	135.0	.....	89.2	69.8	66.4	57.0	44.8	.....	115.6	.....	75.0	69.4	52.6	43.8	36.8	.....

*Mean of two determinations. **Regular sample broken, 24-Hr. P.F.T. Effluent Sample Settled and used for Replacement.

APPENDIX B

RESULTS OF ANALYTICAL DETERMINATIONS

Suspended and Volatile Suspended Solids (Continued)

All Results Expressed in Parts Per Million

Date 1945	Suspended Solids								Volatile Suspended Solids							
	Raw	Settled	Applied	Filter A Effluent	Filter B Effluent	Filter A Settled	Filter B Settled	Plant Effluent	Raw	Settled	Applied	Filter A Effluent	Filter B Effluent	Filter A Settled	Filter B Settled	Plant Effluent
July 12	224	106	89	268	104	38	42	53	116	58	64	226	50	21	19	26
13	188	138	102	67	88	58	58	64	122	102	77	47	62	40	44	46
14	160	140	96	85	82	65	61	59	126	112	86	63	60	58	49	48
15	186	108	92	79	89	55	68	61	96	68	72	53	67	36	48	42
16	192	134	118	96	104	60	68	51	168	119	104	82	91	47	58	44
18	214	127	137	113	117	69	67	60	182	97	109	81	88	47	48	.....
19	186	132	123	84	111	55	64	49	160	94	101	62	90	40	49	34
20	168	113	110	86	54	44	86	43	122	88	89	64	48	25	43	21
21	170	126	124	122	121	61	49	52	148	107	108	100	98	46	56	44
22	140	104	114	73	80	47	37	31	130	91	104	62	72	41	34	27
24	166	115	118	93	83	60	46	50	142	94	98	70	62	41	32	36
25	150	95	103	82	70	42	31	36	128	86	93	75	64	34	27	31
26	162	102	106	80	81	34	31	37	132	89	84	64	65	29	27	37
27	176	112	120	98	73	52	47	43	152	89	107	74	55	39	36	32
28	138	118	120	83	87	49	41	41	126	111	110	68	74	46	37	37
30	190	124	136	75	98	48	62	41	156	108	96	58	79	36	48	33
31	176	84	122	72	77	34	43	35	140	73	90	51	61	26	36	26
August 1	262	107	160	98	90	48	59	25	160	82	112	68	59	34	36	21
2	242	146	204	117	142	66	77	64	214	182	186	103	130	60	71	61
3	174	122	122	109	112	59	65	53	124	76	72	66	88	38	48	35
5	112	92	70	60	56	35	30	35	100	76	62	56	50	31	28	26
6	162	114	106	84	68	47	42	48	124	94	90	64	57	34	29	38
7	174	112	96	74	60	33	38	40	142	94	80	62	50	28	32	34
8	200	112	90	69	51	36	40	43	160	94	76	54	40	32	33	37
Mean	178	116	116	95	88	50	52	46	140	95	95	74	69	38	40	35
	Samples Composited Over Maximum 4-Hour Period															
July 22	206	.....	196	99	93	67	48	.....	196	.....	182	86	79	60	44	27
27	286	.....	176	101	97	79	67	.....	251	.....	161	85	80	65	56	32
Mean	246	.....	186	100	95	73	58	.....	224	.....	172	86	80	63	50	30

APPENDIX B

RESULTS OF ANALYTICAL DETERMINATIONS

Nitrogen Determinations

All Results Expressed in Parts Per Million

Date 1945	Free Ammonia Nitrogen				Total Organic Nitrogen				Nitrite Nitrogen				Nitrate Nitrogen			
	Raw	Applied	Supernatant		Raw	Applied	Supernatant		Applied	Supernatant		Plant Effluent	Applied	Supernatant		Plant Effluent
			A	B			A	B		A	B			A	B	
									24-Hour Composite							
Mar. 19	1.7	3.0	2.3	2.0	7.0	7.8	5.0	5.0	0.7	0.4	0.5	0.5	1.6	3.4	3.4	3.2
20	1.2	1.2	0.45	0.25	6.2	6.2	3.1	2.8	0.8	0.5	0.5	0.5	2.0	5.2	6.0	4.0
21	2.2	1.4	0.4	0.2	7.0	6.4	2.5	2.5	1.0	0.5	0.2	0.5	0.0	5.0	5.0	6.0
24	4.5	4.4	2.4	2.4	12.8	11.2	5.3	5.6	0.45	0.4	0.4	0.55	0.0	5.0	6.0	6.0
25	5.0	4.4	2.5	2.5	12.6	10.9	5.6	6.2	Tr.	0.7	0.6	0.60	0.0	4.0	4.0	4.0
26	5.0	6.0	2.0	2.0	8.4	10.0	4.5	3.9	Tr.	0.45	0.45	0.50	0.0	4.0	4.0	4.0
27	6.0	5.5	2.4	2.5	15.1	12.3	6.7	5.6	Tr.	0.55	0.55	0.90	0.0	3.0	3.0	2.0
28	5.5	7.0	1.8	2.0	12.3	12.3	4.5	5.6	Tr.	0.60	0.55	0.70	0.0	3.4	3.2	6.0
29	4.0	6.0	4.0	2.0	10.1	11.8	4.5	4.8	Tr.	0.60	0.60	0.90	0.0	3.0	3.0	2.0
30	3.5	5.0	4.4	3.8	9.8	10.6	5.6	5.6	0.09	0.55	0.60	0.60	Tr.	6.0	6.0	6.0
Apr. 1	2.0	12.0	3.0	3.0	9.8	11.5	5.0	4.9	0.07	0.4	0.4	0.45	Tr.	4.0	4.0	4.0
2	6.0	5.0	3.6	3.2	12.3	10.9	3.9	4.5	0.06	0.42	0.45	0.55	Tr.	5.0	5.0	5.0
3	10.0	7.5	4.4	4.0	19.2	14.0	4.5	4.2	Tr.	0.65	0.60	0.65	Tr.	5.0	5.0	5.2
4	6.0	4.5	3.6	3.2*	14.3	10.4	5.6	.....	0.008	0.60	0.55*	0.60	Tr.	5.0	5.0*	5.0
5	6.0	6.0	3.6	3.6	10.4	10.1	5.0	5.3	0.009	0.50	0.45	0.50	Tr.	3.8	4.0	4.0
7	5.0	5.0	3.6	3.6	14.0	14.3	4.2	5.3	Tr.	0.60	0.50	0.50	Tr.	3.4	3.6	3.4
8	5.0	5.5	4.0	3.8	13.7	12.2	5.0	5.3	Tr.	0.60	0.64	0.60	Tr.	3.2	3.0	3.2
9	8.5	7.0	4.4	4.4	19.0	15.4	8.1	7.3	0.017	0.80	0.90	0.90	Tr.	4.8	5.2	5.0
10	7.0	6.0	4.0	3.6	18.2	14.8	8.7	5.3	Tr.	0.60	0.65	0.65	Tr.	4.0	4.2	4.4
11	7.0	6.0	4.4	4.2	15.5	14.8	.....	.....	Tr.	0.55	0.50	0.55	Tr.	6.0	5.4	6.0
Mean	5.06	5.42	3.06	2.81	12.4	11.4	5.1	4.9	0.16	0.55	0.53	0.61	.....	4.31	4.4	4.42
					Samples Composited Over Maximum 4-Hour Period											
Mar. 26	7.0	7.0	2.0	2.0	.....	11.2	5.3	4.2	.....	.....	.....	.....	.....	.....	.....	.....
28	6.0	7.0	2.6	2.0	12.3	12.3	5.3	5.0	.....	.....	.....	.....	.....	.....	.....	.....
Apr. 4	7.0	6.0	3.2	3.4	14.8	15.4	5.9	5.3	.....	.....	.....	.....	.....	.....	.....	.....
7	7.0	6.0	3.6	3.8	14.3	14.0	5.0	5.3	.....	.....	.....	.....	.....	.....	.....	.....
10	5.0	5.0	3.4	3.4	16.0	15.7	8.1	5.0	0.075	0.40	0.40	.....	Tr.	4.6	4.2	.....
Means	6.4	6.2	2.84	2.92	14.35	13.72	5.92	4.96	.....	.....	.....	.....	.....	.....	.....	.....

Regular sample broken.

APPENDIX B

RESULTS OF ANALYTICAL DETERMINATIONS

Nitrogen Determinations (Continued)
All Results Expressed in Parts Per Million

Date 1945	Free Ammonia Nitrogen				Total Organic Nitrogen				Nitrite Nitrogen			Nitrate Nitrogen		
	Raw	Applied	Filter A Effluent	Filter B Effluent	Raw	Applied	Filter A Effluent	Filter B Effluent	Applied	Filter A Effluent	Filter B Effluent	Applied	Filter A Effluent	Filter B Effluent
July 12	3.0	4.5	2.0	3.0	14.61	12.60	9.43	9.86	0.0150	0.240	0.290	0.16	1.44	1.20
13	5.0	7.0	4.4	4.0	18.20	15.18	10.92	10.42	0.0150	0.137	0.063	0.04	0.16	0.12
14	5.0	8.5	7.3	8.0	15.26	17.50	11.12	13.24	0.0150	0.313	0.015	0.04	0.12	0.08
15	7.5	8.5	9.5	9.5	16.80	15.96	12.60	12.80	0.0075	0.138	0.188	0.04	0.28	0.08
16	11.0	13.0	11.0	9.0	21.00	18.37	14.81	14.59	0.0025	0.088	0.138	0.04	0.10	0.06
18	9.0	9.0	9.0	8.5	16.52	17.36	14.00	13.83	0.0025	0.188	0.113	0.02	0.12	0.10
19	10.0	10.0	12.0	9.5	21.90	22.34	16.80	15.40	0.0010	0.313	0.025	0.04	0.48	0.06
20	13.0	14.0	12.0	12.0	20.86	19.60	16.38	16.07	0.0030	0.575	0.088	0	0.52	0
21	16.0	16.0	18.0	15.0	20.72	23.52	18.73	19.07	0	0.013	0.025	0	0	0
22	12.0	12.0	12.0	12.0	18.20	20.50	14.64	16.13	0	0.138	0.188	0	0.10	0.22
24	8.0	10.0	8.0	8.0	17.92	17.36	15.96	15.68	0.0120	0.013	0.088	0	0	0.06
25	13.0	13.0	9.0	11.0	17.42	17.14	12.24	12.18	0	0.100	0.375	0	0	0.36
26	12.0	12.0	11.0	9.0	16.94	16.30	12.35	12.88	0	0.113	0.313	0	0	0.30
27	12.0	10.0	8.0	9.0	16.80	16.52	12.52	12.68	0.0030	0.063	0.525	0	0	0.22
28	10.0	10.0	9.0	9.0	18.76	18.54	14.00	13.72	0.0040	0.188	0.575	0	0.10	0.30
30	12.0	12.0	11.0	11.0	18.76	18.79	15.48	13.78	0.0080	0.213	0.025	0	0.04	0.02
31	12.0	12.0	11.0	11.0	22.60	19.35	16.02	14.22	0	0.450	0.088	0	0.08	0
August 1	12.0	12.0	7.0	9.0	17.84	16.88	13.10	11.06	0	0.600	0.063	0	0.10	0.02
2	12.0	11.0	9.0	10.0	20.16	18.90	13.55	13.05	0	0.475	0.050	0	0.01	0
3	15.0	16.0	14.0	14.0	19.54	18.82	15.96	14.67	0	0.475	0.063	0	0	0
5	16.0	12.0	11.0	12.0	20.50	17.11	13.19	12.49	0.0210	0.625	0.725	0	0.06	0.02
6	16.0	15.0	13.0	14.0	19.88	19.04	14.56	14.90	0	0.600	0.525	0	0.04	0.04
7	17.0	15.0	14.0	15.0	22.32	17.64	14.58	14.06	0	0.850	0.650	0	0.06	0.09
8	12.0	12.0	9.0	9.0	17.69	14.64	11.20	10.94	0	0.650	0.550	0	0.07	0.08
Mean	11.3	11.4	10.1	10.1	18.80	17.92	13.92	13.66	0.0046	0.315	0.240	0.02	0.16	0.14

NOTE—No nitrogen determinations were made on 4-hour composite samples collected during second period.

APPENDIX C

Dissolved Oxygen Determinations*

Date 1945	Time	Mean Sewage Temp.	Filter A, p.p.m.		Filter B, p.p.m.		Filter Effluent Channel p.p.m.	Plant Effluent p.p.m.
			East	West	East	West		
March 26.	4:20 P.M.	18.5	5.9	6.3	6.1	6.3	6.0	6.0
27.	3:45 P.M.	17.4	6.2	6.3	6.6	6.6	6.4	5.2
29.	11:00 A.M.	15.9	6.8	7.0	7.0	7.0	6.9	6.0
30.	1:30 P.M.	15.6	6.7	6.8	7.0	7.0	6.8	6.3
April 3.	3:15 P.M.	17.9	5.9	5.8	6.0	6.2	5.9	5.3
4.	2:10 P.M.	14.6	6.7	6.5	6.9	7.0	6.5	6.4
5.	10:00 A.M.	14.9	6.7	6.8	7.1	7.0	6.8	6.1
12.	9:20 A.M.	17.0	6.7	6.4	6.6	6.6	6.6	4.8

*All dissolved oxygen determinations were made on grab samples.

REFERENCES

(1) Walton, Graham, High Daily Rate Trickling Filter Performance. Published under the direction of the Board of State Health Commissioners, Upper Mississippi Sanitation Agreement. March 1943.

(2) Barnett, G. R., The Use of Sodium Azide in the Winkler Method for the Determination of Dissolved Oxygen. Sewage Works J. 11, 781 (1939).

(3) Placak, O. R., and Ruchhoft, C. C., Determination of Biochemical Oxygen Demand. Comparative Study of the Azide and Rideal-Stewart Modifications of the Winkler Method. Ind. and Eng. Chem. Anal. Ed. 13, 12 (1941).

(4) Ruchhoft, C. C., Report on the Co-operative Study of Dilution Waters Made for the Standard Methods Committee of the Federation of Sewage Works Associations. Sewage Works Journal 13, 669 (1941).

(5) Ruchhoft, C. C., and Placak, O. R., Studies of Sewage Purification XVI. Determination of Dissolved Oxygen in Activated Sludge Sewage Mixtures, Sewage Works J. 14, 638 (1942).